Alberta

MUNICIPAL AFFAIRS

Innovative Housing Grants Program

RESIDENTIAL GUIDELINES FOR FLOODPLAIN CONSTRUCTION

November 1987

Prepared by:

Victor Kozak
Stephens Kozak Architects Ltd.

The views and conclusions expressed and the recommendations made in this report are entirely those of the authors and should not be construed as expressing the opinions of Alberta Municipal Affairs.

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FOREWORD

The project documented in this report received funding under the Innovative Housing Grants Program of Alberta Municipal Affairs. The Innovative Housing Grants Program is intended to encourage and assist housing research and development which will reduce housing costs, improve the quality and performance of dwelling units and subdivisions, or increase the long term viability and competitiveness of Alberta's housing industry.

The Program offers assistance to builders, developers, consulting firms, professionals, industry groups, building products manufacturers, municipal governments, educational institutions, non-profit groups and individuals. At this time, priority areas for investigation include building design, construction technology, energy conservation, site and subdivision design, site servicing technology, residential building product development or improvement and information technology.

As the type of project and level of resources vary from applicant to applicant, the resulting documents are also varied. Comments and suggestions on this report are welcome. Please send comments or requests for further information to:

Innovative Housing Grants Program
Alberta Municipal Affairs
9925 - 107th Street
Edmonton, Alberta
T5K 2H9

Telephone: (403) 427-8150

ACKNOWLEDGEMENT

The basis of this report was an extensive literature search of current North American flood plain management practices.

A primary source of information has been the library service of Alberta Environment as well as the resources of the Planning Division. In addition, the U.S. Army Corps of Engineers has been in the forefront of floodproofing technology in the United States and along with the Federal Emergency Management Agency have contributed a large number of reference publications to the existing pool of knowledge.

The City of Edmonton through its River Valley Redevelopment Planning Group circulated a Floodproofing Mail Questionnaire in 1985 to all Canadian Municipalities known to have flooding problems and the results of this survey were made available to us. This information expanded on the ground breaking survey conducted by James F. MacLaren Ltd. in 1977, the results of which formed the basis for their report "Flood Proofing, A Component of Flood Damage Reduction". This was the first comprehensive Canadian literature on the subject.

Contact has been made with all readily accessible and relevent agencies to obtain documentation regarding their experience and current position on floodproofing as a viable flood damage reduction alternative. These agencies are listed in Appendix A.

In addition, we wish to acknowledge the review and comments provided by Dr. Bruce MacLock, Alberta Environment.

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EXECUTIVE SUMMARY

INTRODUCTION

There is interest on the part of some individuals and municipalities in maintaining or developing residential properties in areas which could be subject to flood damage. Much of the effort done to date in North America to alleviate flood damage has consisted of major structural work such as dams, reservoirs and levees. These are approaches to control flooding and are expensive. In view of ongoing pressures to maintain and expand development in flood prone lands, there is growing interest in preventative measures such as land use guidelines, development regulations in floodplains and floodproofing. To date, floodproofing has not been actively explored or promoted in Canada, but some evidence indicates that floodproofing may be one of the best preventative measures in terms of cost effectiveness. Floodproofing also refers to techniques which are implementable by individual households and/or builders. Further, information on such techniques are not readily available in a convenient format for these potential users.

This study was initiated in response to the situation described above. It gathered, reviewed and consolidated current knowledge on the topic and applied it to the Alberta context. More specifically, the objectives of the study were to:

1) review the flood threat in Alberta municipalities;
2) recommend urban planning, site development and servicing techniques which are suitable to minimize flood damage in small scale residential developments located in floodplain areas;
3) propose retrofit techniques which can be applied to existing residences in order to minimize flood damage;
4) propose suitable floodproofing techniques which can be applied to new construction in Alberta communities threatened by flooding; and
5) estimate the cost-effectiveness of specific floodproofing measures.

CONTEXT

Alberta has a well documented history of flooding with most major urban areas experiencing floods on a regular basis. Edmonton, Calgary, and Ft. McMurray have the most heavily impacted communities.

Floodplain management is a provincial responsibility which is carried out through Alberta Environment. Alberta's policy in this field is contained in the publication "Water Resource Management Principles for Alberta", where it is noted that flood plain management is pursued to minimize potential flood damage and the main advocated methods include warning systems, zoning controls, control structures, purchase of flood-prone lands and insurance programs. In line with this policy, Alberta Environment strongly advises against development of a permanent or intensive nature on those portions of undeveloped floodplains that have a probability of one or more floods every 100 years. Floodproofing is not currently promoted. In fact, floodproofing efforts are sometimes limited by a lack of two-zone flood risk mapping of floodplains which makes provision for flood fringe areas where new, correctly designed construction can take place.

FLOODPROOFING ALTERNATIVES

Floodproofing alternatives can be grouped in two broad categories: dry floodproofing and wet floodproofing. Dry floodproofing is generally supported on the basis that a new or existing building should not be allowed in the floodplain unless the interior can be kept completely dry. The major alternatives available in dry floodproofing are listed below:

- elevating structure on fill;
- elevating structure on extended foundation (continuous concrete or block wall);

- elevating structure on piles or columns;
- floodwalls and levees (berms);
- seals and closures; and
- other miscellaneous techniques (barging, sheeting).

Wet floodproofing involves intentional flooding by either potable water or flood water. The purpose of intentional and controlled flooding is to balance flood forces acting on the structure. This avoids the complete loss of structural integrity that could result from basement uplift or foundation wall collapse, but offers little protection for building contents.

The final report on the study discusses each of the floodproofing techniques and develops guidelines for their application. The report also outlines floodproofing guidelines with respect to site design, site services and utilities and building services (heating, plumbing and electrical services).

FINDINGS AND CONCLUSIONS

There is a clear distinction between the approach to floodproofing of proposed new buildings and those already present in the floodplain. Retrofitting of floodproofing measures for existing structures is almost entirely site specific and should be undertaken only with a full knowledge of structural details and existing structural conditions. The decision to floodproof an existing building depends upon factors such as the structural material, age, substructure conditions, as well as the nature of flooding, height of water, sewerage facilities and uses demanded of the building.

In general, the most practical method of floodproofing new residential structures is to elevate the structure above the design flood level. Other methods of floodproofing should be considered only when there are

no other alternatives. Since most existing and many new residential structures typically do not have the structural integrity to resist hydrostatic forces, dry floodproofing measures can be costly when any habitable space is located below the design flood level. Another major concern is occupants' safety.

The cost analysis conducted in this study indicated cost premiums for incorporating floodproofing measures outlined below:

Technique	Premium New	Premium Retrofit
Elevation on Raised Fill	5%	47%
Extended Foundation	6-10%	30-37%
Elevation on Piles	6%	19%
Floodwalls	36%	36%
Wet Floodproofing	6%	17%

It is clear that floodproofing could be accomplished in the flood fringe in a variety of ways, generally at a relatively moderate cost in new buildings.

The premium to floodproofing existing houses is substantially higher and varies considerably depending on the nature of the existing structure and the technique selected. These costs should be balanced against the life expectancy of the building, the cost of periodic damage and cleanup if no action is taken, and the threat to life.

1.0 INTRODUCTION

There is a growing interest in some major urban areas in Alberta by individuals and municipalities to not only maintain existing neighbourhoods but increase residential development in areas which have been subjected to periodic flooding. A key to reducing flood losses and the risk to life and property is an integrated flood plain management programme. Flood plain management incorporates many techniques to control development in flood plains, one of which is the use of floodproofing measures. Although much has been written about floodplain management and floodproofing techniques over the last 15 years, the information is scattered and not readily available to the average homeowner or builder. This study has attempted to gather, review and consolidate the current knowledge on the topic and present it in an Alberta context.

More specifically, the objectives of this study were to:

1) review the flood threat in Alberta municipalities;
2) recommend urban planning, site development, servicing design and construction techniques which are suitable to minimize flood damage in small scale residential developments, such as family residences, duplexes, townhouses and walk-up apartments, located in floodplain areas;
3) propose retrofit techniques which can be applied to existing residences in order to minimize flood damage;
4) propose suitable floodproofing procedures which can be applied to new construction or site developments in Alberta communities threatened by flooding; and
5) estimate the cost-effectiveness of specific solutions to provide a basis for the homeowner to evaluate alternate scenarios.

This report documents the results of the work.

Although development in flood plains in Alberta is not generally encouraged, it is not always avoidable. Floodproofing provides a means of protection for structures either already located within or proposed for a flood plain area. This report attempts to provide the necessary information to assess floodproofing as a viable alternative in a flood plain management programme.

It was not the intent of this study to focus on major flood damage prevention such as flood control mechanisms (i.e. dams and reservoirs, channel improvements, levees or walls). However, chapter 4.0 Flood Damage Reduction Alternatives will review all elements of prevention planning in order to provide a context and framework within which floodproofing can take its place as a viable component.

This study has as its base a literature search of existing resources and contact with involved agencies to determine relevant experience and current practice regarding flood damage reduction alternatives with specific reference to small scale residential facilities and related municipal services.

The literature search has focused on:

1) jurisdictional matters pertaining to existing flood control regulations and programmes;
2) technical and design techniques of floodproofing as a component of flood damage reduction alternatives;
3) legislative impediments to implementation of effective damage control measures;
4) cost effectiveness of alternate solutions; and
5) experience of other jurisdictions and the effectiveness of similar efforts.

2.0 NATURE OF FLOODING

2.1 HISTORICAL BACKGROUND

Flooding occurs naturally as one part of the earth's hydrologic system. When this natural event is combined with man's historical affinity for settling near water it can produce the potential for disaster. Man has tended to settle in fertile low-lying areas, close to drinking water sources, irrigation reserves and livestock watering supplies. In Canada, rivers were widely used for both transportation and water power, therefore, river banks and lakefronts were natural and logical for settlements. Rivers often became transportation corridors, providing access for roads and railways and subsequently industrial development which took place on the easily built upon flood plains rather than on river banks or higher ground. Low-lying land was also favoured as being cheaper to supply with water since less pumping was required.

Today there is no reason to locate new communities in the path of floods. However, once a settlement has been established with its infrastructure of roads, services, utility supply, etc. it is not easily abandoned. The cost of resettlement en masse is generally prohibitive and often not desired by the inhabitants. Consequently, any effort made to provide interim protection often serves to increase the heavy investment in the area and reduces the possibility of relocation even more.

In recent times, population and land cost pressures in developed areas have often led to building expansion into flood prone areas. Often, the scenic and recreation qualities of river and lakefront areas make them very appealing for development and an attractive location for a new home.

However, all the perceived advantages of river and floodplain areas have been a mixed blessing since overflowing watercourses continue to cause property damage, income loss and often loss of life.

Millions of dollars of public funds have been spent by federal and provincial governments in the payment of disaster relief and in the repair and rebuilding of community services. In addition, huge amounts of money have been spent on major flood protection schemes such as dams and dikes.

Despite these losses, floods have not discouraged settlement in river valleys. In fact, occupation of floodplains has been increasing at a rate more rapid than overall population increase. In Canada and the United States, it has been estimated that at least 12% of the population lives in areas subject to inundation, with the proportion increasing in both cases.

The 1978 study by James F. MacLaren Ltd. (reference 20), came to the following conclusions:

> "It is generally recognized that the alleviation of flood damage in North America has been accomplished to a large extent in the past by the construction of structural works such as retention reservoirs, channel improvements, and stream diversions. However, due to continued urban development pressures to expand into flood prone lands, a reliance on only structural measures will lead to a spiralling increase in capital expenditure on associated flood protection actions and an increase in flood losses. It is also known that annual damages from flooding in Canada are increasing in spite of the many millions of dollars the Federal and Provincial governments are devoting to these flood protection works. The conclusion is simple - a program using only structural measures for reducing flood damages cannot achieve complete success in Canada."

> "Floodproofing of buildings in low hazard areas, or the use of techniques for "flood resistant" construction, is increasingly considered as one of the best alternatives for reducing flood losses to a new or existing structure or small group of structures. If correctly used, floodproofing will play a significant role in a comprehensive floodplain management program."

2.2 TERMINOLOGY

Hydrologists think in terms of the frequency and extent of floods. Baselines for high water have been established based on the possibility of re-occurance of the event. Historic records have been kept of the maximum water level which has occured in a given time period.

The common unit of flooding is the **One-Hundred Year Flood** - a flood having a one-percent chance of occurring in any given year and which, over a very long period of time, can be expected to be equalled or exceeded on the average of once every hundred years. It is also referred to as a **100-Year Frequency Flood** which is a flood having an average frequency of occurrence in the order of once in 100 years or that there is a 1% chance of such a flood in any year. Normally, the 1% probability of occurrence, based on a flood of specific designated magnitude, is a 'standard' adopted by some provinces and accepted by the Government of Canada.

This allows us to establish a **Design Flood Level (DFL)** which is the level which would result from the high water of record. In Alberta, this is the 100 year flood level or one-percent chance flood level. It is used to indicate the minimum flood elevation to be used by a community as a basis for its flood plain management regulation. It is often referred to in literature as the Base Flood Elevation.

The **Flood Construction Level (FCL)** is the DFL plus a variable allowance for Freeboard. It is used to establish the minimum elevation of the underside of the floor system for habitable buildings. It also generally establishes the height of the top of any berms or levees. CMHC requires a minimum 300 mm Freeboard.

Additional important terms are covered in Appendix I: Definitions.

2.3 TYPES OF FLOODS

At least four types of river and lake flood may be recognized according to the physical factors involved. These are:

1) snow-melt floods,
2) ice-jam and ice break-up floods,
3) convectional storm floods, and
4) cyclonic storm floods.

This typology is useful because it is possible to associate certain characteristics with each, though rarely can a flood be ascribed to a single cause. The latter two are more often associated with coastal or hurricane prone areas whereas in Alberta the first two types are most prevalent.

Snow-melt floods most often occur in the early spring when a winter's accumulation of precipitation may be liberated and flow off of a watershed within a short period. Such floods are most likely to occur after an unusually heavy season of snowfall, and in areas where snowfall is normally heavy. They are also associated with a rapid thaw process as when the temperature rises rapidly after a long cold period and stays high for several days. The Winnipeg Red River flood of 1950 and the Edmonton flood of 1986 are examples of snow-melt flood. In Winnipeg, for example, there was heavy snowfall in the winter and an above-normal accumulation at break-up. Important contributory factors were that the thaw or break-up came later than usual, the soil moisture content was high due to a wet autumn, the ground was frozen and above-normal rainfall also occurred during break-up. Ice-jams were an additional cause of flooding on a few tributaries.

Ice jams and ice break-up floods often occur in the early spring, and are a type of flood common to most of Canada. Ft. McMurray is Alberta's best example of a community perennially plagued by ice-jam floods. Ice-jam floods may occur to any time during break-up and are not necessarily more likely to happen when the state of the river is high. Such floods are more frequent when there is an abundant quantity of ice jammed together to form a temporary dam. These ice-jams occur at constriction points such as a sharp bend, a gorge, a bridge- crossing or any other physical obstacle. Other contributing factors are the thickness of the ice and the direction of the river. For example, problems may arise on north-flowing rivers, where the downstream sections remain

jam develops the water often rises behind it very rapidly so that the rate of rise of an ice-jam flood is often much sharper than that of a snow-melt flood.

2.4 EFFECTS OF FLOODS

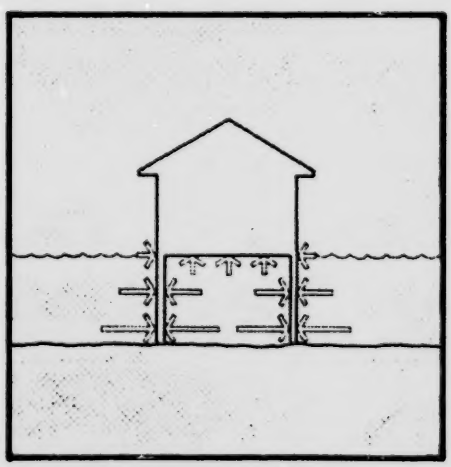
Before any structure is built, Engineering analysis is required to determine the expected loads that will be placed on it. The magnitude, the point of application and the direction of the forces must be determined. Normally, the loads that are considered in residential construction are dead load and gravity live load.

However, when building in a floodplain, additional loads may be placed on the structure by a floodwater environment.

Few people realize the force of flood waters. A 100-mile-per-hour wind blowing on the side of a house would be equal to about 12 inches of water flowing at 10 miles per hour against the same wall even though the distribution of forces would be different. Water 1-foot deep flowing at 20 miles per hour against the wall would be 4 times as strong as a 10-mile-per-hour water current at the same 1-foot-depth.

This chapter summarizes the additional loading conditions and forces that must be considered when a structure is located in a flooding environment.

HYDROSTATIC PRESSURE AND FORCES: Hydrostatic forces result from the static mass of water at any point of flood water contact with a structure. They are equal in all directions and always act perpendicular to the surface on which they are applied. Hydrostatic loads can act vertically on structural members such as floors and decks, and can act laterally on upright structural members such as walls, piers, and foundations.



HYDROSTATIC FORCES

Figure 1 (reference 4)

Lateral loads in the form of hydrostatic pressure affect underwater portions of a house in the same way that water pressure affects a diver. Greater depths of water exert greater pressures on the structure.

At a depth of 5 feet (an average below grade depth of basement walls) water exerts over 300 pounds of pressure per square foot of surface. Fortunately, there is frequently a tortuous path through relatively impervious soil from water on the surface to basement walls and to the under side of the basement floor. Otherwise water pressure from a flood or a heavy rain could easily break the average basement slab floor.

Buoyancy (Figure 2):

An object in water is buoyed by an upward force equal to the weight of the water displaced. Each cubic foot of water that is displaced by the structure exerts enough buoyant force to float about 62 pounds. This upward movement is opposed by two forces - first, the weight of the house and its furnishings, and second, by the frictional shear forces of the soil against the underground foundation walls and footings.

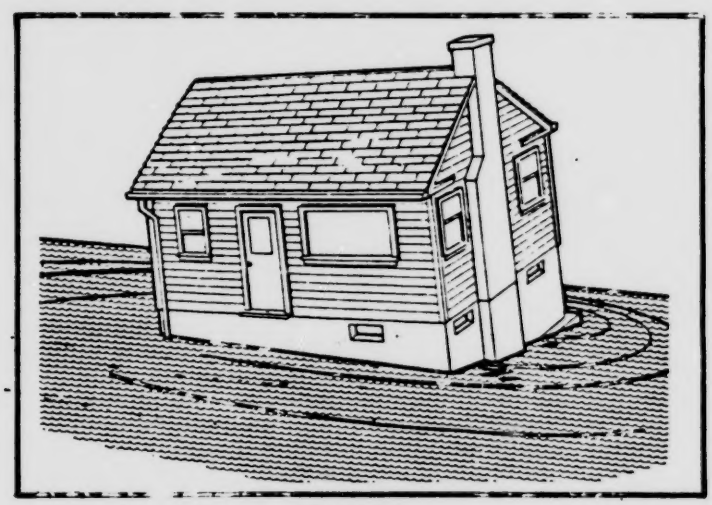
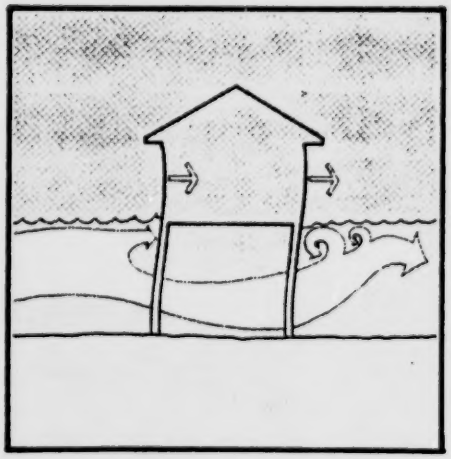


Figure 2 BUOYANCY (reference 24)

An average 1-story house with basement could reach a buoyant condition and begin to float out of the ground when outside water has reached about 3 feet above the level of the basement floor. Fortunately, the entire wall and underfloor areas are not fully saturated in most cases. The buoyant condition is caused by only those areas that are saturated. As a consequence, buoyant basements are less frequent than a simple application of the basic laws of physics would predict. Most basements also have an effective, but not very efficient, built-in protective device. Underslab upward hydrostatic loads will usually rupture the floor slab before a buoyant condition is reached. This allows water to flow into the basement and reduces the amount of water displaced.

The basementless house will float if trapped air inside the house displaces enough water. An average 1-story house will float when water reaches about to the eaves.

HYDRODYNAMIC FORCES: (Figure 3)
Hydrodynamic forces result from the flow of flood water around a structure, including a drag effect along the sides of the structure and eddies or negative pressures on the structure's downstream side. This can result in Scouring (figure 4) and eventual Erosion (figure 9) of the foundation support. These forces are more common in flash floods, coastal floods, and when flood water is wind-driven.



HYDRODYNAMIC FORCES
Figure 3 (reference 4)

Overturning (Figure 5):
Rushing water or wave action can combine with buoyant forces or a bottom snagging effect to overturn a structure onto its side.

Battering (Figure 6):
The battering of rushing water, waves, or objects floating in the water can create extensive danger.

Battering waves can destroy masonry or concrete structures which have limited lateral strength. Reinforcing steel, properly added during construction, can greatly improve resistance to the impact of waves. Coastal buildings are sometimes built with breakaway wall panels on the ground floor. These panels are sacrificed to the wave action while the piles or piers continue to support upper floors of the house and present relatively little surface to impact of the waves.

Pulsating Water (Figure 7):
Pulsating action is most pronounced inside the house. Water rushing in is stopped by an opposite wall and returned toward its place of entry. These oscillations can approach a natural frequency of pulsation, which sustains and amplifies the motion. Floating contents and debris, caught up in the oscillating motion, can act as battering rams. Furnishings and structural elements may be seriously damaged by these pulsating waters.

Translation (Figure 8):
Unless an effective sill anchoring system is used houses may be pushed off their foundations by moving water. Such lateral movement of the structure is called translation. If forces from water occur unevenly around the building, it may rotate. Buoyant force, by reducing dead weight of the structure, can make a house more vulnerable to translation.

Another hydrologic factor is ice, which in northern climates can cause serious damage to structures if flooding should occur during the spring before the ice melts. In some cases winddriven ice or ice jams have completely demolished bridges, homes, and businesses, snapping large trees and pushing buildings completely off their foundations. Floating debris can be equally dangerous in this regard. There is little that can be done to avoid these phenomena short of avoiding sites where they are especially likely to occur.

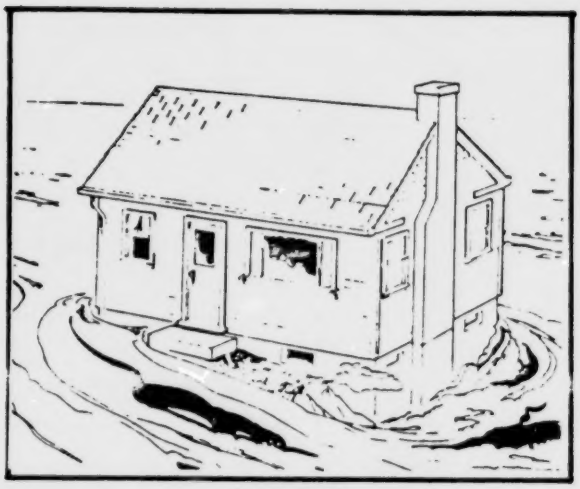


Figure 4 SCOURING (reference 24)

Figure 5 OVERTURNING (reference 24)

Figure 6 BATTERING (reference 24)

Figure 7 PULSATING (reference 24)

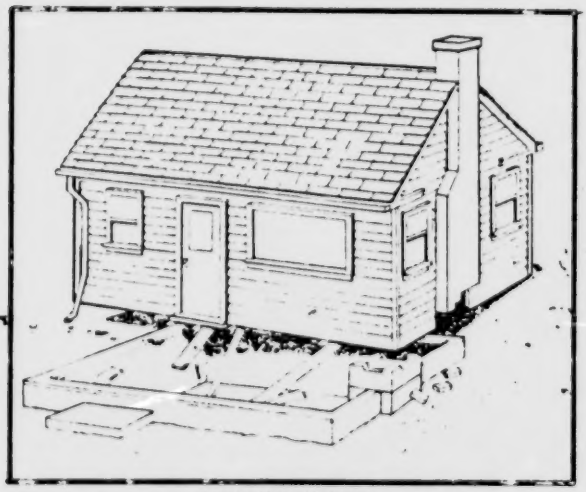


Figure 8 TRANSLATION (reference 24)

Figure 9 EROSION (reference 4)

2.5 FLOOD THREAT IN ALBERTA

As Table 1 indicates, this Province has a well documented history of flooding with most major urban areas experiencing floods on a regular basis. Figure 10, exerpted from the Alberta Environment Flood Information Index, is a map showing the recorded flood areas in Alberta in this century. A description of the problem in some specific communities follows:

Edmonton

In Edmonton, there are two older residential areas, Rossdale and Cloverdale which are located in the river valley and are heavily affected by periodic flooding. A large percentage of the Rossdale community, particularly South Rossdale, lies within the 1:100 year floodline of the North Saskatchewan River basin. The line was established at 622.8 m above sea level by Alberta Environment and is based on a 1974 study, updated with more recent contour and computer modelling techniques. It is a theoretical approximation but generally exceeds existing grade by .65 - 1.0 metres. The floodway channel has been assumed to be within the 1:25 year flood line and is essentially within the Capital City Recreation Park boundary and the Restricted Development Area. Development is restricted within these areas by provincial legislation and since this restriction is recognized in the Edmonton Land Use Bylaw as a land use restriction overlay, residential development in the floodway is thereby prohibited.

One hundred sixty of Rossdale's 175 lots (91.4%) are either fully or partially in the flood fringe area; of these, 58 are between the floodway and the 1:50 year flood line.

Rossdale has experienced several floods over the years, with the highest recorded peaks occurring in 1899, 1900, 1915, 1952, 1954 and 1972. The most severe flood occurred in 1915, after a week of rain, at which time the river flooded some portions of Rossdale to a depth of ten feet. Fifty homes were swept downstream while another 700 were flooded . City power and water pumping stations located in the area at the time were also damaged, and the Low Level Bridge was in danger of being swept away. The situation was compounded by the breach of the old wooden Brazeau Dam. More recent floods have been less severe.

TABLE 1

SUMMARY - HISTORICAL FLOODING CLIPPINGS

(reference 3)

RIVER AND VICINITY	FLOODING YEARS[2]
Athabasca River vicinity of: :Athabasca :Ft. McMurray :Whitecourt	1909, 1913-15, 1920, 1932, 1934-40, 1943, 1945, 1947, 1948-52, 1954-56, 1960-63, 1965, 1969, 1971-72, 1975.
Bow River vicinity of: :Banff :Calgary	1909, 1915-16, 1918, 1923, 1928-29, 1932-33, 1940, 1942, 1948-53, 1954, 1956, 1959, 1963, 1965, 1967, 1972, 1974
East & West Prairie River vicinity of: :High Prairie :Enilda	1926-27, 1929, 1930, 1934-35, 1948-49, 1951-55, 1957-58, 1963, 1964, 1965, 1971, 1973-75.
Elbow River vicinity of: :Bragg Creek :Calgary	1915, 1923, 1929, 1932, 1942, 1948, 1953, 1965, 1967, 1969.
North Saskatchewan River vicinity of: :Edmonton :Rocky Mountain House	1915, 1923, 1936, 1942, 1944, 1952, 1954, 1956, 1965, 1972
Oldman River vicinity of: :Lethbridge :Ft. MacLeod	1916, 1923, 1929, 1934, 1942, 1947-48, 1952-53, 1955, 1964, 1972, 1975.
Paddle & Pembina Rivers vicinity of: :Jarvie :Rochfort Bridge :Entwistle	1914-15, 1917, 1935-36, 1944, 1948, 1954-56, 1965, 1967, 1971-72, 1974
Peace River vicinity of: :Peace River :Ft. Vermilion	1915-58, 1960-65, 1968-69, 1971-75.
Red Deer River vicinity of: :Drumheller :Red Deer	1913, 1915, 1920, 1923, 1925, 1928-29, 1932, 1939-40, 1943-44, 1947-48, 1951-55, 1965, 1967, 1970, 1972.
Sturgeon River vicinity of: :St. Albert :Ft. Saskatchewan	1936, 1940, 1943, 1948, 1956, 1965, 1971, 1974

Rivers with limited clipping information on flooding are:

Clearwater River

MacLeod River

Pine Creek

Slave Lake Area

South Saskatchewan River

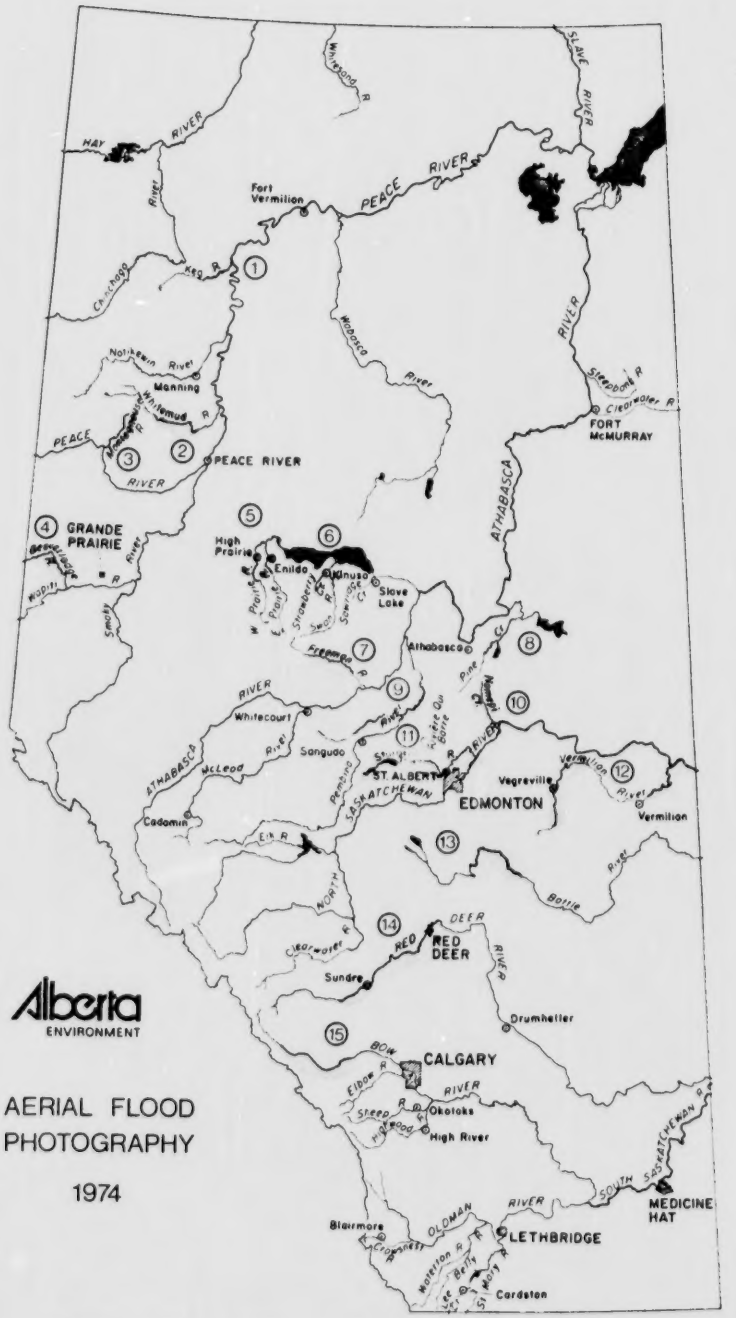
Vermilion River

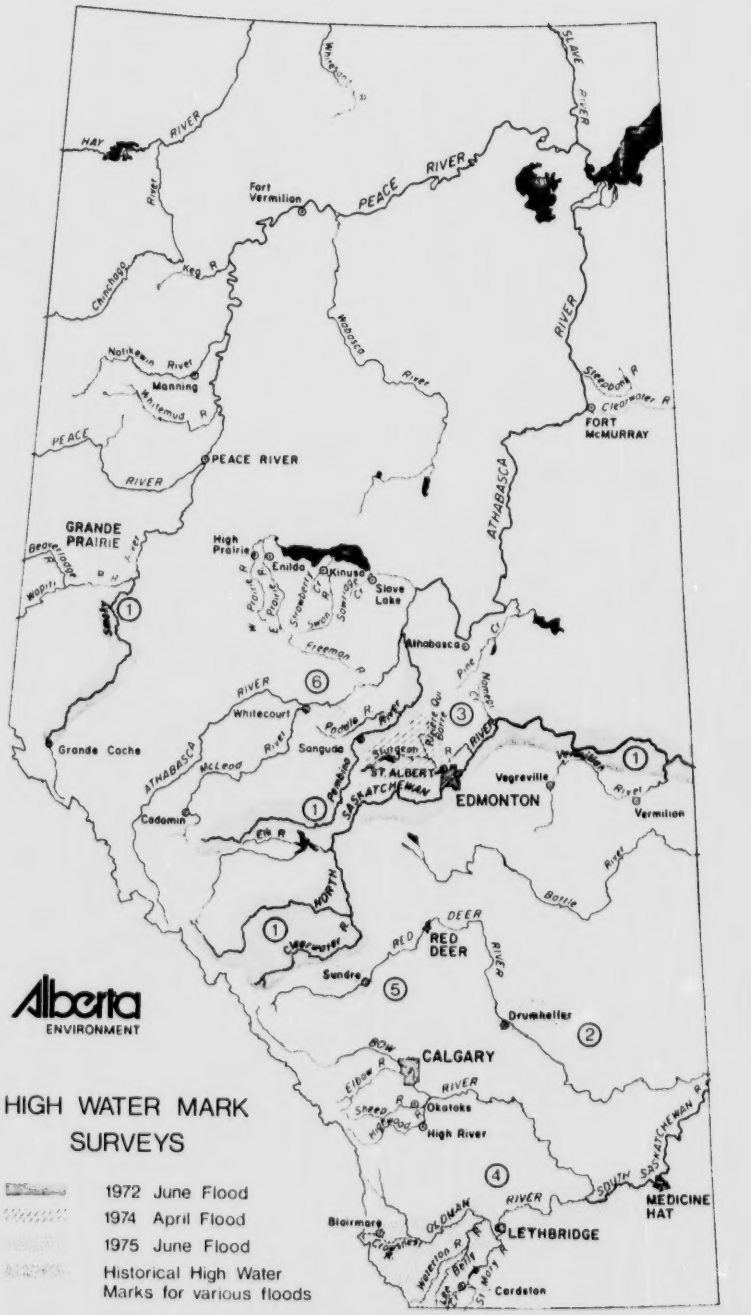
1. Clippings available in Alberta Environment Library.

2. Apart from those underlined, the years summarized contain clipping information of all kinds (surface, subsurface) and magnitudes (significant, minor). For the years which are underlined, high flows were recorded, however, no clippings were available.

FLOODING MAPS

Figure 10





(reference 3)

The Cloverdale Community has 35 of 179 lots in the flood fringe area.

The completion of the new Brazeau Dam in 1961 and Big Horn Dam in 1972 reduced the impact of flooding in Edmonton but they did not eliminate the risk. These dams were built primarily for low flow water augmentation, not flood control. Although they do reduce flow levels, it is still possible to have flood peaks which exceed the record 1915 flood.

In 1986 Edmonton City Council reversed a long standing policy of buying up residential properties in the floodplain. It decided to allow the existing communities to remain as well as approved new residential development in the river valley.

Red Deer

Red Deer is located on the floodplain of the Red Deer River. The main part of the city lies below the bluff of a former meander scar on the southeast bank of the river. There is a small community on the northwest side of the crossing, and in recent years the city has expanded both along the floodplain and on to the top of the bluff. The valley is subject to ice-jam floods during the winter months, and snow-melt floods in spring and early summer, especially when a rapid thaw is associated with heavy and persistent rainfall. Flooding has occurred mostly in floodplain areas above and below the city, and in areas peripheral to it. The highest summer flood level was in 1915. The highest level recorded due to ice-jams was in 1943. The April, 1943 flood was perhaps the worst on record doing thousands of dollars worth of damage. Upstream, the Red Deer River rose more than 15 feet in less than one hour at about 4 a.m. The ice-jam broke at 7 p.m. and the water level fell eight feet in one hour. People living on the west side of the river had barely enough time to get out of their houses before the tide of the water rushed in. A number of houses were flooded to depths of 18 inches. The most tragic flood however, was the ice-jam flood of March 26, 1947 in Red Deer which resulted in five deaths.

In 1960 an engineering report was submitted to the city of Red Deer indicating that there were two separate land areas on the floodplain usable for industrial development, and that each could be enlarged considerably by land filling and berm construction. The report did not describe in detail the calculations upon which these recommendations were based but the suggested fill and berm construction is considered protection for the areas recommended for development from floods of a 200-year frequency. Such a flood has not occurred in the period since the establishment of the city. The summer flood of 1915 has an estimated frequency of once in 50 years.

Calgary

The potential for flooding in Calgary is greatest during the June-July period when mountain runoff is at its peak and severe summer storms are most likely to occur. The risk of winter flooding has been reduced because of construction of Bearspaw Dam on the Bow River in 1954, reduction in monthly winter flows, dikes built through the central parts of the city and construction of the Ice Pack Anchorage in 1959 downstream of Louise Bridge. Although the above works have reduced the probability of a severe winter flood, a potential hazard remains as illustrated by the winter flood of 1966 when the dikes adjacent to Hillhurst/Sunnyside were topped by flood waters.

Bearspaw Dam, is utilized for generating electricity and for controlling only short term flow fluctuations in the Bow River. According to the Montreal Engineering report, "City of Calgary Flood Study, Volume 1, Bow River Report", dated May 1973, significant summer flooding in Calgary will occur when flows in the Bow River (above the Elbow) are of the order of 20,000 to 25,000 cubic feet per second.

The City of Calgary experienced three major floods during the period 1879-1902 which were more severe than any since experienced. The flood of 1897 on the Bow River, with a peak flow of 80,000 cubic feet per second above the Elbow River and an estimated return period of once in 70 years, would have affected about 2,500 dwellings and 350 commercial and industrial establishments.

Since that time there has been further development in the floodplain. At the end of August 1979, there were approximately 2,059 single-family houses, 553 multi-family buildings and 239 commercial and industrial establishments located in the floodplain of the Bow River. Most of the redevelopment and new development, excluding Bow Village, Point McKay, Deer Run developments, Eau Claire and the Federal Government office building, were not required to comply with the current floodplain management policy of City Council.

Based on 1973 values, Montreal Engineering estimated that damage from a flood of 80,000 cubic feet per second would be about $10 million. These estimates were based on the assumption of idealized flow conditions; the possible blockage of bridges or failure of stream bans were not considered. Taking into account new development and inflation factor, the damage estimate for 1987 would not be less than $62 million in the case of 1:70 year flood on the Bow River. An estimate of the 1:100 year flood damages for Calgary was not undertaken.

With construction of Glenmore Dam on the Elbow River in 1982, the 1% probability flood of 29,400 cubic feet per second has been reduced to 26,800 cubic feet per second (refer to "Calgary Floodplain Study - Volume 1", April 1983, by Alberta Environment).

According to the Monenco Consultants report "Elbow River Flood Study", about 462 houses, 26 apartment buildings, and 3 other buildings would have been affected in the event of a flood of 1% probability with a designated flow of 20,300 cubic feet per second downstream of Glenmore Dam. Additionally, 20 apartment buildings, 770 houses and about 34 other buildings outside the floodplain of the Elbow River would have been affected by sewer backup. Including the damages and destruction to utilities and bridge structures, total potential damages would be in the order of $18.2 million updated to 1987 dollars.

3.0 GOVERNMENTAL & INSTITUTIONAL CONSIDERATIONS

3.1 ALBERTA FLOOD CONTROL REGULATIONS & PROGRAMMES

Flood Plain Management Programs are a provincial responsibility with the provinces of Ontario, British Columbia and Alberta being the most active. However, major floods have prompted the involvement of both Provincial and Federal governments in initiating a National Flood Damage Reduction Program in 1975. This Program is designed to identify flood-risk areas and discourage people from building within them. Under Flood-Risk Mapping Agreements with the provinces, flood-prone areas are mapped in order that builders, lenders and municipal and provincial authorities can be made aware of the hazards, and so prohibit, or at least control, their building programs.

Although Alberta has not joined the program as of this date, it has established a floodplain management policy outlined in the publication "Water Resource Management Principles for Alberta" (reference 2), which states that "As a basic principle, floodplain management it pursued in order to minimize potential flood damages. Management methods may include warning systems, zoning controls, control structures, purchase of flood-prone lands, and insurance programs. Alberta Environment strongly advocates that no development of a permanent or intensive nature be allowed on those portions of undeveloped flood plains that have a probability of one or more floods every 100 years."

This approach has been favoured by some communities such as Red Deer where it has been the policy over the past few years of the Red Deer Regional Planning Commission to reject applications for new development in its river valley. All residential proposals were rejected in conformance with the policy of Alberta Environment. In conjunction with this policy, flood plain lands have been steadily purchased as they became available so that today there is no existing residential property within the floodplain. City Planners do not forsee any development pressure within the City of Red Deer which would reverse this policy. There has been some industrial property developed in the flood fringe by using earth fill techniques to raise structures above the DFL.

Some municipalities in Alberta are not acting in accordance with Alberta Environment's position on restricting floodplain development and are proceeding on their own. This indicates that there is a necessity for an integrated approach to floodplain management involving all levels of government since floods are not restricted by municipal or even provincial boundaries.

As noted previously in 1986 the City of Edmonton commenced a programme of actively encouraging new development in the river valley. A report was produced for the City of Edmonton by Nasedkin McKellar Architects (reference 25) outlining recommendations for low density infill housing development in the river valley communities. Since the main thrust of the report was how to preserve the character of the existing neighbourhoods, it concluded that any new residential construction should maintain the current relationship to grade.

The Nasedkin McKellar study rejected any alternatives which would raise new buildings substantially above the DFL and essentially supported the "wet" floodproofing alternative. "Wet" floodproofing involves intentional flooding by either potable water or flood water. It is discussed in Section 4.4.

The Alberta Government is prepared to cost share with local authorities on all water management projects from which direct public benefits accrue. Examples of such projects include flow regulation, lake stabilization, flood control and protection, and municipal water supply and sewage disposal facilities. The provincial share of the cost ranges from 100% on projects of major provincial benefit to smaller proportions on purely local projects. Guidelines and criteria have been established in several position papers.

In addition Alberta Environment has conducted studies of it own which include:

1) accumulation of historical flood data,
2) aerial flood photography,
3) flood risk maps, and
4) floodplain studies.

Appendix B outlines the nature and extent of these studies to date.

Flood prone areas adjacent to a community's waterways consist of a **Floodway** area and a flat land **Flood Fringe** area immediately adjacent to the floodway. In the event of a major flood, the hydrological significance of these areas differs since the former is critical to the passage of floodwaters whereas the flood fringe areas are primarily subject to inundation. Floodplain management policies for development in the floodway and floodfringe areas reflect this difference.

Under Flood-Risk Mapping these flood-prone lands are described as being a One-Zone or Two-Zone area.

1) A One-Zone approach (Figure 11) is where the flood-risk area is defined as the land inundated by the **Design Flood.** The definition of **Design Flood** varies from province to province but is not less than the 1-in-100 year event as is the case in Alberta.

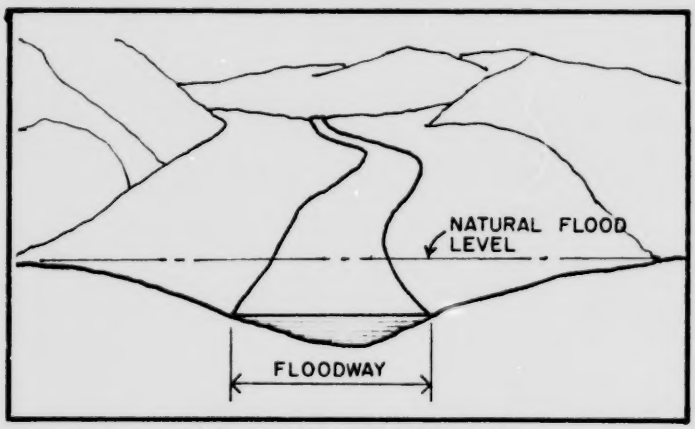


Figure 11 ONE-ZONE FLOODPLAIN

2) A Two-Zone approach (Figure 12) is where both a **Floodway** and **Flood Fringe** area are delineated. In a Two-Zone approach, the **Design Flood Level** is determined by taking into account the final level of all lands which could be raised by earth fill during development in the **Flood Fringe** area. Using this approach, the overall flood-risk area is greater than under natural conditions, but the **Flood Fringe** area can be used for flood-proofed construction.

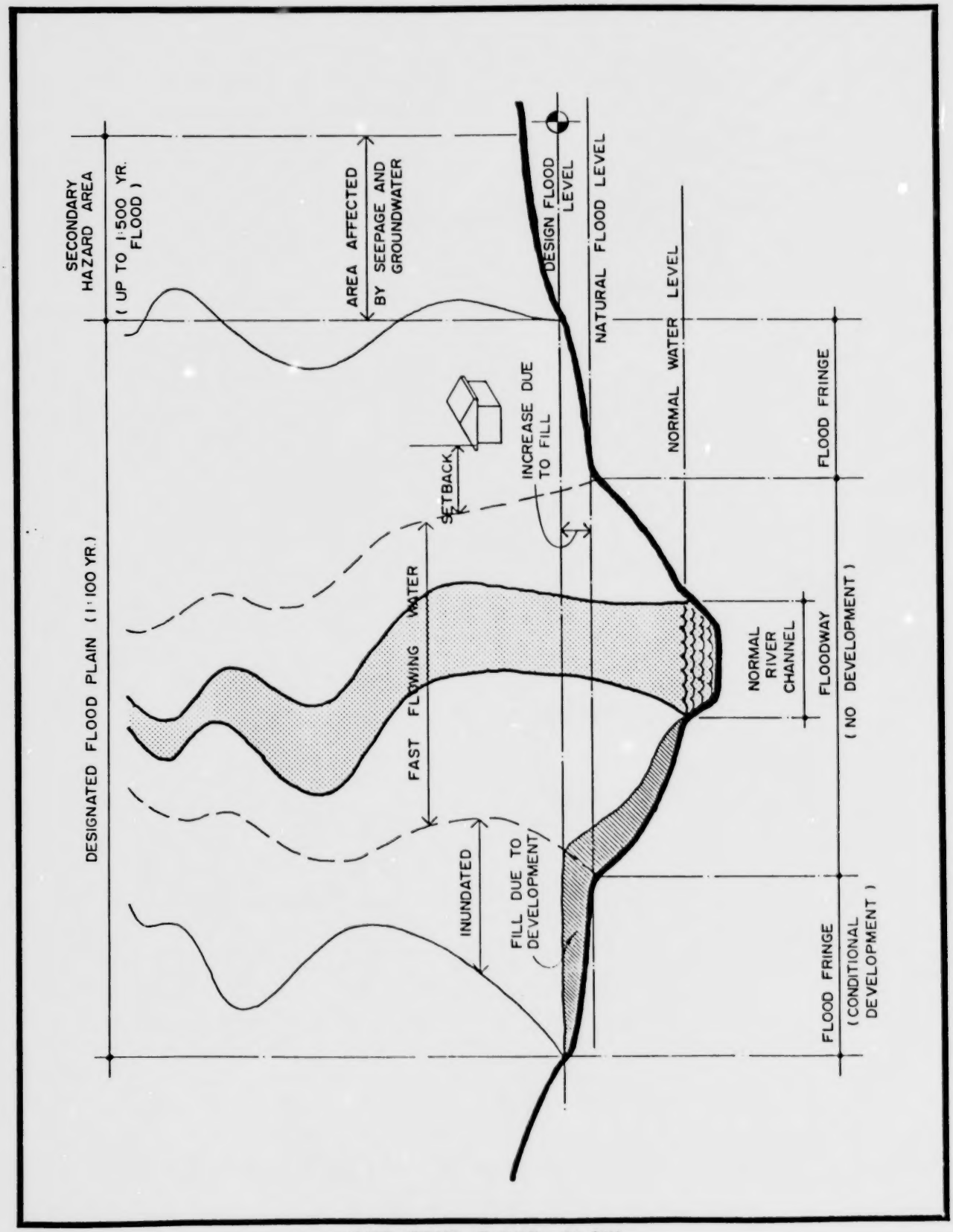


Figure 12

TWO-ZONE FLOOD PLAIN

The Alberta Building Code 1985 edition does not address the issue of floodproofing individual structures. Control of construction techniques currently lies with agencies such as CMHC or individual municipalities which have set down zoning bylaws governing floodplain development or have required mandatory floodproofing techniques to be employed in new construction.

3.2 LEGISLATIVE IMPEDIMENTS

In Canada, regulation of natural resource development including waterways is a provincial and not a federal responsibility. This has discouraged the federal government from taking the interest in flood problems that has now come to be expected from the United States government. The federal government, in Canada, can take action on all rivers deemed navigable, and on interprovincial rivers but in general has refrained from doing so. In the past, the role of the federal government in connection with flood damage reduction has been remedial in providing disaster assistance following major floods and preventative in supporting the provinces in the assessment and implementation of vital flood control projects. Flood problems have remained almost entirely in provincial hands and each province's view of flood problems differs widely. The National Flood Damage Reduction Programme was a major step in Federal/Provincial cooperation.

Floodproofing as a viable flood damage reduction measure has not been actively promoted in Canada, although it is now an accepted technique in the United States. In 1974 the U.S. Water Resources Development Act listed floodproofing as one of the "nonstructural" alternatives that must be given consideration in federal projects involving flood protection. The full range of alternatives is described in chapter 4.0.

Floodproofing has often been discouraged by lack of flood risk mapping or by one-zone floodplains which make no provision for fringe areas upon which new, correctly designed construction can take place. Alberta is not currently part of the National Flood Damage Reduction Program initiated in 1975 but is considering joining it and designating flood plains in up to 50 communities. With the exception of the Monerco study of Calgary's floodplains, very little Two-Zone floodplain mapping has been done in this Province.

Federal programes such as NHA financing require that new housing projects can be financed only if all of the following conditions as set down by CMHC are met:

1) a floodway is delineated in the building area.
2) the project is located in the flood fringe area, not the floodway, and
3) specific floodproofing requirements are met.

This does not preclude residential construction since other financial institutuions may provide mortgages subject to an appraiser's analysis and the flood susceptibility of a particular property. Further discussion of funding implications is covered in chapter 3.4.

The Alberta Water Resource Act Amendment 1960 gives the Environment Minister the necessary authority to prevent development of floodplain lands. Although this has not been enforced, the policy of Alberta Environment is to discourage floodplain development. This policy may affect the Province's role in encouraging alternative methods to reduce potential flood damage and compensation.

Since flood lines cross municipal boundaries, the lead in establishing flood zones must be taken at the provincial level in order to maintain uniformity in regulations.

Possible Government Actions

The difficulty with any mandatory requirement for implementation of flood damage reduction methods lies primarily in ensuring compliance in existing structures. There is no easy way to order retroactive compliance specifically to prevent flood damage. Some existing structures are not worth retrofitting and may indeed be a hazard to neighbours during a severe flood. If floodproofing were mandatory under municipal building or maintenance codes, then retrofit could be ordered and, if not performed by the owner voluntarily, could be done by the municipality and charged against taxes. However, the legal and political difficulties inherent in such an approach are serious obstacles to its implementation. Government would have to decide which units were worth saving and which would have to be condemned as hazardous.

Community measures such as levees or dikes may be more easily undertaken by the municipality with the cost spread over the population. The complexity of ownership and interests would probably make it difficult for a self motivated coordinated neighbourhood effort; therefore, the inducement would probably have to come from government.

It may be possible for the Province or municipalities to offer financial incentives such as grants or low interest loans to homeowners within floodplains to floodproof existing residences. Alternatively, expropriation could be used to buy out, retrofit and floodproof then resell residences which are substandard.

In the absence of construction guidelines in the Alberta Building Code, individual municipalities may include mandatory floodproofing regulations within their own zoning bylaws. A review of bylaws from other municipalities affected by flooding indicates that often the following items are generally included:

1) regulations regarding structural alteration, extension and enlargement of existing uses;
2) regulations regarding repairs (restriction, for example, if the structure is 50 percent destroyed);
3) prohibition of basement living quarters; and
4) regulations regarding floodproofing measures that must be taken.

3.3 EXPERIENCE OF OTHER JURISDICTIONS

The experience in the U.S. has shown that floodproofing techniques are proving to be an accepted and effective flood damage reduction alternative but that the diversity of solutions can lead to problems if not properly monitored. Some studies note that in up to 50% of the cases where floodproofing was used failure resulted because of improper implementation.

In 1968 the U.S. National Flood Insurance Act offered subsidized flood insurance contingent upon proper floodplain management. This was the first real impetus to rational floodplain use in the United States. Floodproofing as such was not mentioned in the Act but raised elevation floodproofing soon appeared as an appropriate protection against flood losses for residential structures.

Over the next 5 years watertight (dry floodproofing) standards were continuously enforced and no openings in residential buildings were allowed below the base flood level (set by 1 in 100 year flood). Basements, for example, were only allowed in the floodplain under exceptional circumstances (such as for storm cellars) and wet floodproofing was rejected since it did not comply with performance standards of the Act. Recently, floodproofed basements have been allowed in designated floodplains if they are watertight and the lowest uncontrolled opening is above the 100 year level. Elevation of all residential areas above base flood levels continued to receive the greatest support and financial encouragement.

In the U.S. excellent documentation is being produced but the problems are, to a large extent, site specific and subject to the political will of the authority having jurisdiction. There are however sufficient examples of ordinances we can review which serve to guide development and construction within floodplains.

In many communities, production and dissemination of guidelines and manuals appears to have produced the desired acceptance of alternative measures. The U.S. Army Corps of Engineers has published a comprehensive set of floodproofing regulations that are used by many communities as the basis for their building codes.

The U.S. Federal Insurance Administration now generally considers a residential building insurable against flood damage if it is elevated on fill or columns to a level equal to the 1 in 100 year flood. Closures and seals or floodwalls are not recognized as acceptable for residential structures, although flood walls/berms have been used as justification for floodplain mapping amendments.

Non-residential buildings may be dry floodproofed by any approved method at all - but the insurance rate structure is still weighted in favour of elevation. For example, bulkheads must be extended an additional 1 foot above the same regulatory elevation that would be required if elevation on fill or columns were selected. In the final analysis, elevation floodproofing appears to be the growing trend. More followup is required to assess the effectiveness of certain other techniques since in many cases no flooding has occurred since new construction of the remedial measure has taken place.

In Canada, an example of an integrated program for flood control involving all levels of government in land use planning and building regulations is the British Columbia Floodplain Development Control Program, administered by the Ministry of Environment, which has been in operation since 1974, and is based on the following principles:

1) identification of flood risk areas and education of the public through widespread distribution of flood risk maps;
2) recommendations on the management of floodplain lands;
3) review of subdivisions, official regional, settlement and community plans and zoning by-laws;
4) encouragement of public awareness including publication of residential construction guidelines; and
5) establishment of flood warning systems and emergency preparedness.

In Winnipeg, following the signing of the Canada-Manitoba Flood Damage Reduction Agreement, Floodway and Floodway Fringe were designated in the Interim Flood Risk Map of the City of Winnipeg. In 1981, enabling provincial legislation and subsequent regulations establishing floodproofing criteria came into force. At present development control and floodproofing in the flood prone areas are achieved mainly by applying, in conjunction with the required flood protection level, the floodproofing criteria as included in Manitoba Regulation 9/85 which is administered by the City of Winnipeg.

3.4 MORTGAGING IMPLICATIONS

A critical item often raised during any discussion of residential construction of a floodplain is the availability of mortgage funding. The City of Edmonton, as part of its River Valley Competition guidelines, contacted the major mortgage lending institutions, including Canada Mortgage and Housing Corporation (CMHC), Alberta Mortgage and Housing Corporation (AMHC) and a number of private banks and trust companies.

Private banks in Alberta indicated that they had no special guidelines for financing in flood risk areas. However, they would likely require CMHC to insure the mortgaging, regardless of whether it was a conventional or high risk mortgage situation. Also, they might insist on the homeowner obtaining flood insurance for the property.

Flood insurance is not a standard item in conventional home owner insurance policies and is almost impossible to obtain. After the Edmonton 1986 flood, Alan Wood, vice-president of the Insurance Bureau of Canada's western region warned that homeowners looking for financial relief for flood damages would not find it in their home insurance policy. "The general rule of thumb is that any damage due to rising water, floods, or the overflow of streams is just not covered." (Edmonton Journal, July 20, 1986.)

The concensus amongst Edmonton insurance brokers contacted by the authors was that homeowner's insurance would not be available for residences constructed in a known floodplain. Each case would be reviewed on its own merits but even in the unlikely event that insurance were made available, the deductible would be extremely high, with figures of $10,000 being quoted. Nor would there be any guarantee of renewal in the event of claims being filed. The general feeling was that the risk would be too high for most companies to take on.

None of the private insurers took into account the damage reduction potential of floodproofing. It appears that the onus would be on the individual proponent to demonstrate to and convince potential insurers that proper construction techniques could result in damage-resistant properties.

CMHC has indicated that any new housing project in which they are involved financially (i.e., National Housing Act financing), must conform to the guidelines in the CMHC booklet Building in a Floodrisk Area (NHA 5701 2/84). This guideline states that:

"In spite of the potential dangers of flooding, it is still possible to receive financing under the National Housing Act for housing projects in a flood-risk area, if the following conditions are met:

1) your land is in a Two-Zone area (that is, both a floodway and a flood fringe have been designated)
2) you are building in the flood fringe area, not the floodway
3) your buildings meet CMHC's floodproofing requirements."

The acceptable floodproofing techniques are:

1) raising on fill;
2) raising on posts, piles or piers; or
3) wet floodproofing (allow the basement to be flooded but not damaged).

In any event CMHC states that every site has its own pecularities and each application for funding is judged on its own merits.

Existing development in designated flood fringe areas would still be eligible for NHA financing. However, any new alterations and additions would have to conform to CMHC's flood risk guidelines. Finally, CMHC does not require special flood insurance to secure financing.

AMHC is willing to finance development within a 1:100 year floodline if such development complies with AMHC's lending and insuring policies applicable in floodplains. (See Appendix H.) The only situation in which AMHC currently refuses to finance development is in the identified 25 year floodplain in Fort McMurray.

A fact-finding exercise similar to Edmonton's was undertaken recently by the City of Fredericton primarily directed at private lending institutions. In summary, the findings were as follows:

1) The majority of financial institutions when evaluating a mortgage application do take into account the flood susceptability of a particular property. The basis for determining the flood susceptability would appear to be the actual physical record of flooding as well as information available through the flood risk mapping program.
2) For most institutions, the critical analysis of a property is made by an appraiser. The appraiser determines what effect flooding may have on a property and places a value on the property.
3) Based on the appraiser's analysis, the financial institutions decide as to whether or not they consider the property a worthwhile risk to mortgage.
4) Many institutions indicated that they prefer not to go to a high ratio mortgage in high risk floodplain areas feeling that the purchaser of a property should accept some of the risk in relation to the financing of the property.

In the United States a requirement for compulsory flood insurance for buildings within floodplains has forced compliance with standards set by the insurers. This is similar to the requirement in Canada for NHA finaced homes to meet CMHC floodproofing requirements. Beyond this, in Canada a municipal or provincial requirement for compulsory insurance does not currently exist and the extent of protection required is left to the discretion of individual lending institutions.

It is interesting to note that in the U.S. "wet" floodproofing is not recognized as a valid floodproofing method by the Federal Emergency Measures Agency. It is not recognized as a rate reduction measure for residential structures for insurance purposes.

4.0 FLOOD DAMAGE REDUCTION

4.1 OPTIONS

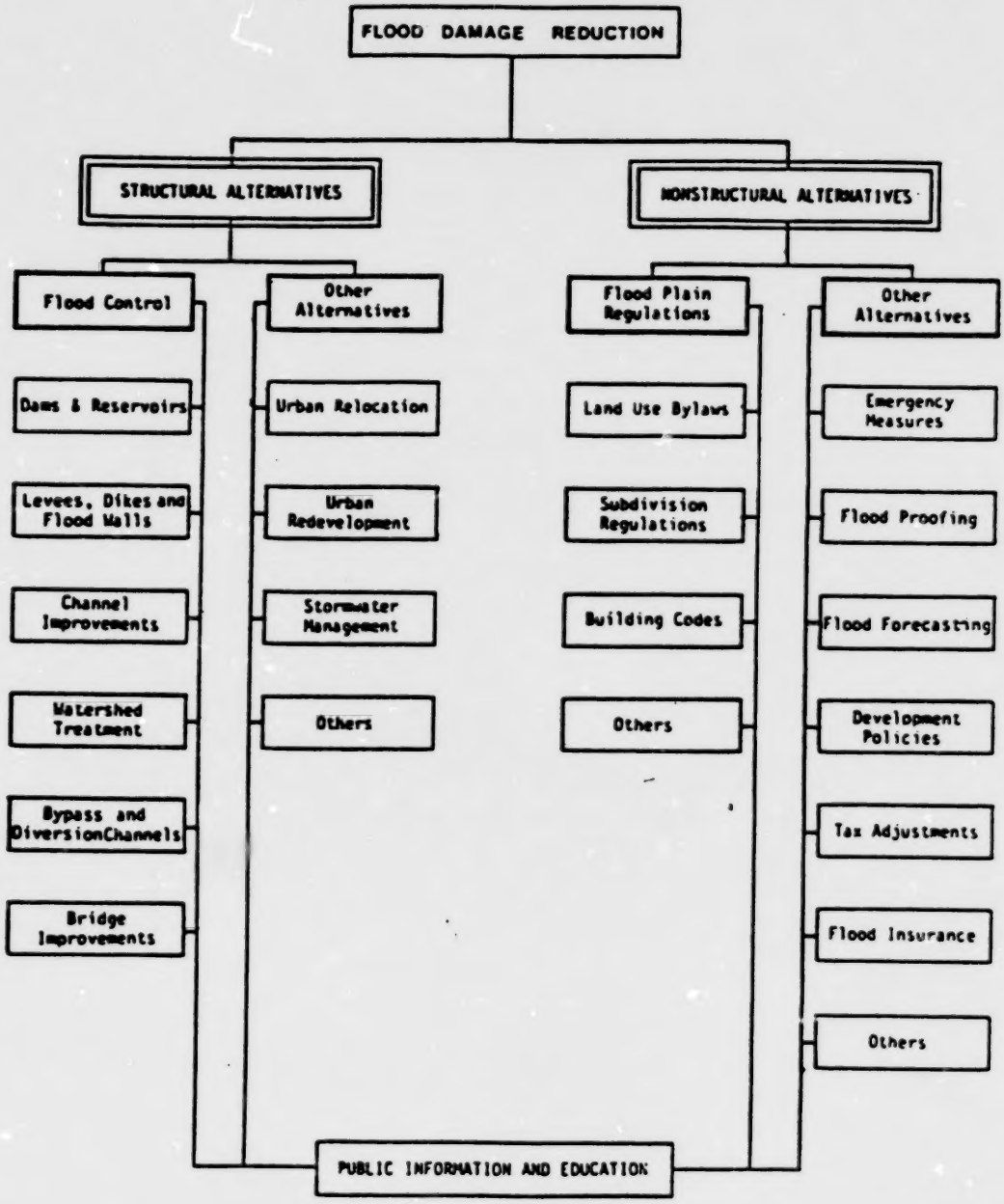
Although there is a wide range of options available for flood damage reduction they can be broken down into two basic approaches. The first, known as "structural" consists of solutions such as dams, reservoirs, levees or major protective works. The second, often referred to in previous studies as "nonstructural", describes a range of solutions which incorporate preventative measures such as land use controls, flood plain regulations and floodproofing.

Figure 13 is a chart prepared by the Tennessee Valley Authority which summarizes a range of possibilities for flood damage reduction under the categories of "structural" and "non-structural".

The term "nonstructural" was initially used in the U.S. to describe the concept of alternate methods of flood control planning and unified floodplain management. The concept that there were a variety of ways which could be used to reduce flood losses to existing and future development was adopted as national policy in the U.S. in 1966. It was accepted that traditional "structural" means, which are designed to control flood waters, are one way of lessening the risk of flood losses; however, there are a variety of other means and these should be used also.

Although floodproofing techniques may in fact involve some structural engineering they are considered, in the accepted North American context of Floodplain Management, to be "non-structural".

Since much of the past work in flood damage reduction and flood plain management was of a corrective rather than preventative nature, "structural" solutions have generally been used to protect existing development. These "structural" alternatives consist of major protective works which confine flood waters or reduce the flood stages for larger areas. They are however expensive to implement and often result in a false sense of security. While these works affect the impact of the selected design flood, substantial damage can result when such floods are exceeded.



SOURCE: From Tennessee Valley Authority 1962.

Figure 13 FLOOD DAMAGE REDUCTION ALTERNATIVES (reference 30)

Generally, "non-structural" alternatives can be classified as preventitive rather than corrective, since they attempt to reduce flood damage by restricting or controlling new development in the flood plain rather than providing protection for existing development.

Measures which have been termed "non-structural" include:

1) regulation of development of floodplain land at the municipal level by master planning overlays, land use and subdivision regulations and building codes;
2) buying up of floodplain land by Municipal or provincial governments for passive recreational use;
3) floodproofing of individual structures or subdivisions;
4) installation of flood forecast and warning systems with an appropriate evacuation plan;
5) adoption of provincial development policies for facilities in or near floodplain land;
6) adoption of tax incentives to encourage wise use of floodplain land;
7) flood insurance;
8) placement of warning signs in the flood plain to discourage development;
9) relocating or protecting damageable property within an existing structure; and
10) relocating existing structures and/or contents out of a flood hazard area.

Not all measures are currently applicable to the Alberta homeowner or builder. However, it can be noted that in the United States the continuing damage due to flooding and the increasing costs of prevention have led to a shift towards a more comprehensive range

of flood damage reduction methods. Attention has turned from total reliance on "structural" methods to include a combination of the "non-structural" solutions as listed above. These softer, generally less costly measures have more possibility of being implemented by individuals or junior levels of government although in order for any floodplain management programme to be completely successful it must result from a coordinated effort among all involved agencies.

This report will now focus on one aspect of the overall framework, the "non-structural" component known as floodproofing.

4.2 FLOODPROOFING - DESIGN METHODS & TECHNIQUES

4.2.1 CONCEPT

Although floodproofing has rarely been considered in Canada as an alternative to zoning or flood protection works, it may be viable under some circumstances. It is most easily incorporated into new construction, but in existing structures the capital outlay for floodproofing individual buildings is often much less than that for expropriation, relocation, or major flood control works.

The potential advantages of floodproofing are greatest in urban sections of metropolitan areas where low-hazard flood lands have already been developed or where great pressure is being exerted, due to building density, to use underdeveloped land in the fringe of defined flood zones. Selective floodproofing can be carried out in these areas often with greater economy than other forms of floodplain management.

Floodproofing is a composite body of techniques and approaches for preventing flood damage to the structure and contents of buildings in flood hazard areas. Examples of floodproofing include the placement of levees, dikes, or walls around individual structures; watertight closures for windows, doors and other openings; wall reinforcement to resist lateral pressure and debris flow; elevation of building on pilings or fill; use of membranes; paint or other substances to reduce water seepage into buildings; and the installation of check valves at sewer and utility locations to prevent the entrance of flood waters.

Floodproofing integrates well with other aspects of flood damage reduction programmes. For example floodproofing is particularly attractive in instances where the Two-Zone concept can be put to use and the floodway fringe can be used. This is the case where other facilities for protecting individual buildings are not practical or economical. Floodproofing could be accomplished in the flood fringe at a relatively moderate cost, encroachment on the floodway would be negligible and the threat to life would be minimized.

A decision to use any one floodproofing method to reduce flood damages must be based on the characteristics of the individual structure. It is important to understand that these techniques are not a guaranteed solution, but rather their success depends on how they relate to the structural condition of a building, local soil characteristics topography, and the type of flooding that will occur.

There are some critical hydrotechnical factors related to flood characteristics which will determine the effectiveness of any floodproofing method:

1) Height of maximum flood level. The lower the depth of flooding the easier it is to floodproof. In lakefront areas, height of wave crests will determine the Flood Construction Level (FCL) and hydrostatic as well as hydrodynamic forces to be expected.
2) Velocity of water flow during flood peaks. The lower the flow velocity the easier it is to design a building to resist flood waters. Velocity influences both horizontal hydrodynamic loads on exposed building elements and impact loads from water borne debris.
3) Duration and frequency of floods. The longer the area is flooded, the more difficult and expensive is the floodproofing since it affects the saturation of soils and building materials.
4) Movement of ice during winter floods can also be important especially in elevated structures.
5) Rate of rise. Indicates how rapidly water depth increases during flooding. This determines warning time before a flood, which will influence the need for access and egress routes elevated above floodwaters and whether or not valuable possessions can be kept underneath the structure and moved only when flooding is imminent.

In general, floodproofing may be applicable in the following situations:

1) where engineering works such as dikes or dams are not feasible but floodproofing could provide a degree of protection;
2) as an interim measure where engineering works are economically justified but will be a long time before completion or until zoning changes the land use;
3) for additional protection where engineering works may be subject to potentially catastrophic failure;
4) in conjunction with engineering works which provide partial protection and individuals wish a higher degree of protection;
5) in place of structural works which modify the flood; and/or
6) where collective action is not possible or individual solutions are desired.

4.2.2 SELECTION

In the design of buildings located in a flood risk area, several problems should be addressed in reducing the threat of flood damage. These include:

- entrance of water through building openings
- damage to building finishes and contents
- seepage through walls, floors, and foundations
- water pressure on foundations, walls, and floor slabs
- back-up of water through sewer systems
- access to and from buildings during floods
- continued power supply.

To deal with these problems adequately, the designer can incorporate a variety of flood damage reduction techniques in building design. These techniques interact with site features and, as with site design, the techniques used for any given project will vary with individual circumstances, needs, and resources.

Floodproofing alternatives (Figure 14) can be summarized as follows:

A. Elevating Structure on Raised Fill
B. Elevating Structure on Extended Foundation (Continous Watertight concrete or block wall)
C. Elevating Structure on Piles or Columns
D. Floodwalls and Levees (berms)
E. Seals and Closures
F. Other Miscellaneous Techniques (barging, sheeting)
G. Wet Floodproofing

There is a clear distinction between the approach to floodproofing of proposed new buildings and those already present in the floodplain. Retrofitting of floodproofing measures for existing structures is almost entirely site specific and is only undertaken with a full knowledge of structural details and existing structural conditions. The decision to floodproof an existing building depends upon factors such as the structural material, age, substructure conditions, as well as the nature of flooding, height of water, sewerage facilities and uses demanded of the building.

In general, the most practical method of floodproofing new residential structures is to elevate the structure above the design flood level. Other methods of floodproofing should be considered only when there are no other alternatives. Since most existing and many new residential structures typically do not have the structural integrity to resist hydrostatic forces, dry floodproofing measures can be costly when any habitable space is located below the design flood level. Another major concern is the uncertainty with respect to the occupants' safety.

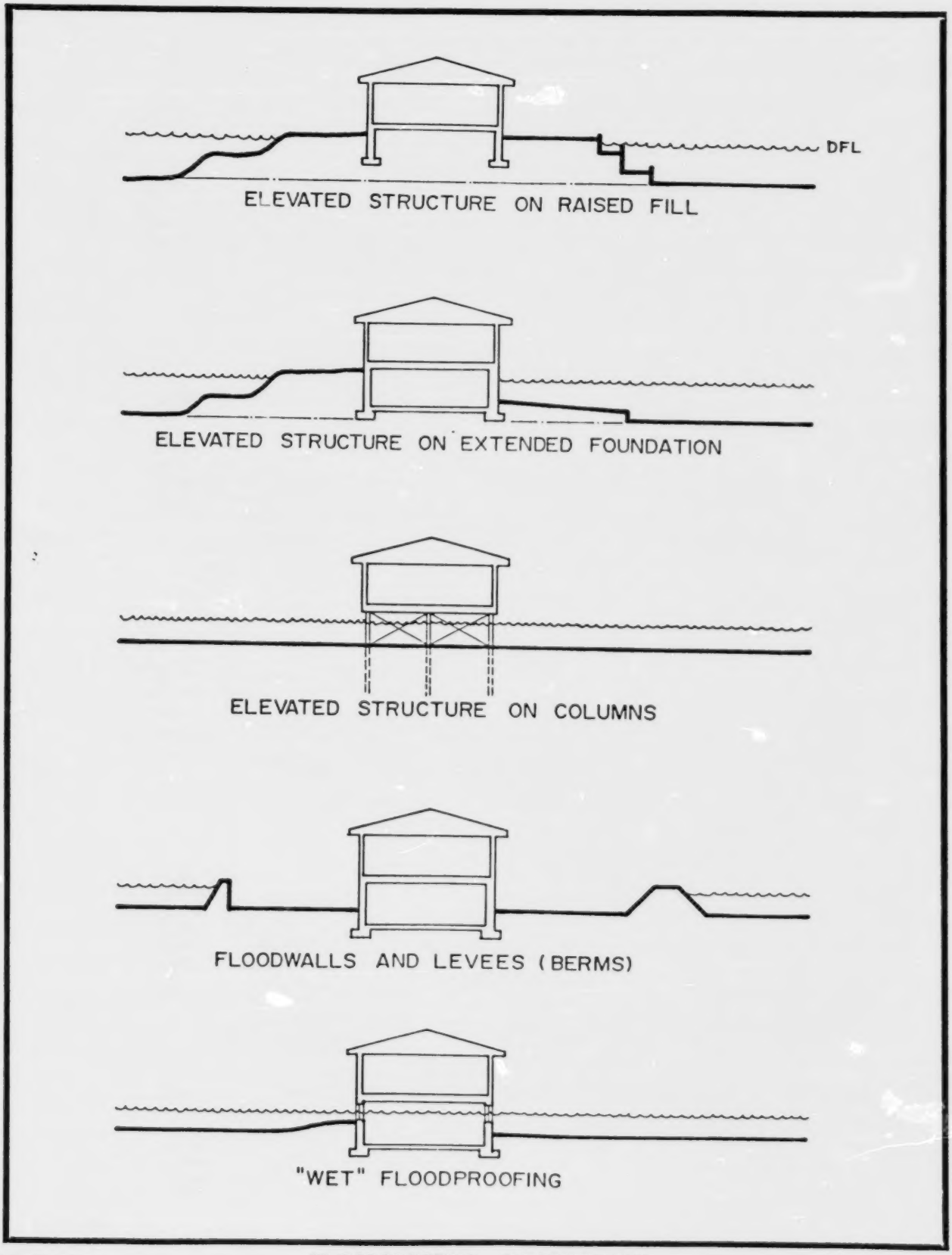


Figure 14 FLOODPROOFING ALTERNATIVES

Any of the floodproofing techniques mentioned can be an effective flood damage prevention measure for both new and existing structures when properly utilized. Likewise, the same measure can be completely ineffective and, if it fails, cause more damage than would have occurred had no attempt to protect the structure been made.

The first basic option for floodproofing involves a decision on whether or not to keep a building and its contents completely dry, or to allow water inside the structure. "Dry" floodproofing is generally supported on the basis that a new or existing building should not be allowed in the floodplain unless the interior can be kept completely dry. The major alternatives available in dry flood proofing which will be discussed in greater detail are A to F above.

The common methods of elevating residential structures are earth fill or elevated foundations such as shear walls, posts, piles, and piers. The selection of an elevation technique depends on a number of variables, including hydrotechnical factors, physical conditions at the site and cost. The determination of the appropriate technique requires analysis of these factors in the context of building code and local regulatory requirements. In some cases it can be advantageous to use a combination of elevation methods. For example, a building raised on fill at one end and piers or posts at the other could provide ground floor access at the end of the building away from the floodplain while minimizing obstruction of flood waters at the end nearer the stream channel (see Figure 15).

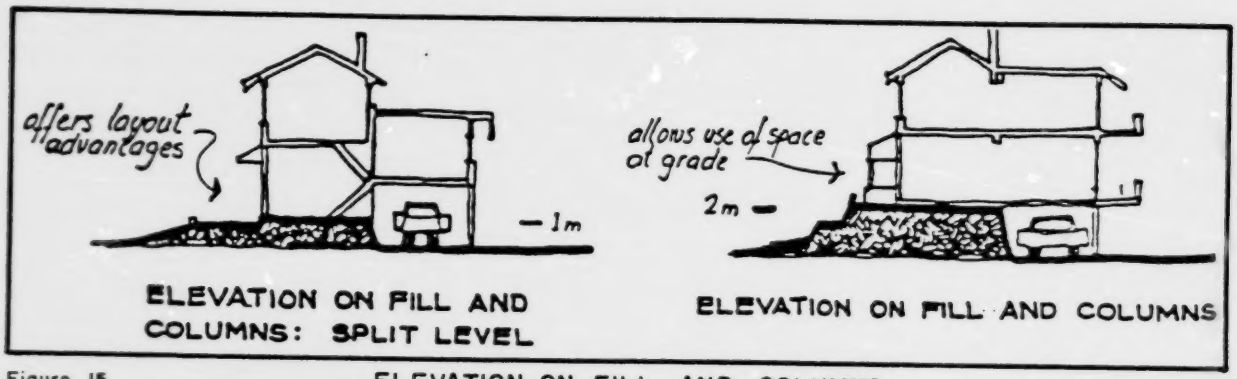


Figure 15 ELEVATION ON FILL AND COLUMNS (reference 27)

Elevating buildings above the Design Flood Level (DFL) is the most widespread technique for reducing flood damage in Canada and the United States. Flood Insurance requirements in the U.S. mandate that residential buildings in flood-prone areas be elevated above the design flood level. This method offers the greatest assurance of keeping a building dry during flooding.

Alternate G, "wet" floodproofing, involves intentional flooding by either potable water or flood water. The purpose of intentional and controlled flooding is to balance flood forces acting on the structure. This avoids the complete loss of structural integrity that could result from basement uplift or foundation wall collapse, but offers little protection for building contents.

On the one hand, "wet" flood proofing is supported by those who feel that use of water resistant materials in flood plain homes is an extra protection against unexpectedly high flood levels. On the other hand however, it is considered by most to conflict with the basic purpose of flood proofing - to maintain a dry condition. At this time in the United States, "wet" flood proofing is not considered as an insurable option and it is doubtful that it would be acceptable to many new homeowners even if it were. However it is one of the techniques approved for NHA (National Housing Act) financing and will be discussed at the end of this section. Also, it is worth considering since it is often the only viable technique for existing buildings to prevent structural damage during excessive flooding.

4.3 DRY FLOODPROOFING

4.3.1 ELEVATION OF STRUCTURE ON FILL (Figure 16)

On sites with low-velocity flooding, where scouring is not a severe problem it is feasible to elevate structures on permanent earth fill. With proper construction techniques and materials, this can be the most economical method of elevating a building two or three feet above grade or in some locations even higher. It has the flexibility of being able to elevate both an individual building or groups of buildings as well as complete new subdivisions.

If a building on raised fill contains a basement and soil saturation is probable, hydrostatic pressures must be considered. For buildings with all construction above the water level and saturation point, such as slab on ground, the critical component in this design is the nature of the earth fill itself.

The characteristics of the soil in a flood area - soil bearing capacity, for example - can be important in determining and appropriate design. Highly erodable soil would not be desirable for use as fill in elevating a structure in a high velocity area unless the fill is properly protected. When erosion due to scouring removes soils supporting building foundations, the foundations can fail.

Since materials available for fill may vary from one locality to the next, a site's topography and soil conditions may preclude economical elevation of the structure on fill. Refer to Appendix C for a complete description of the correct method of placing fill.

Provision must be made for adequate surface drainage and erosion protection. Generally fill material must be grassed and riprapping may be required for critical exposed slopes of a fill pad.

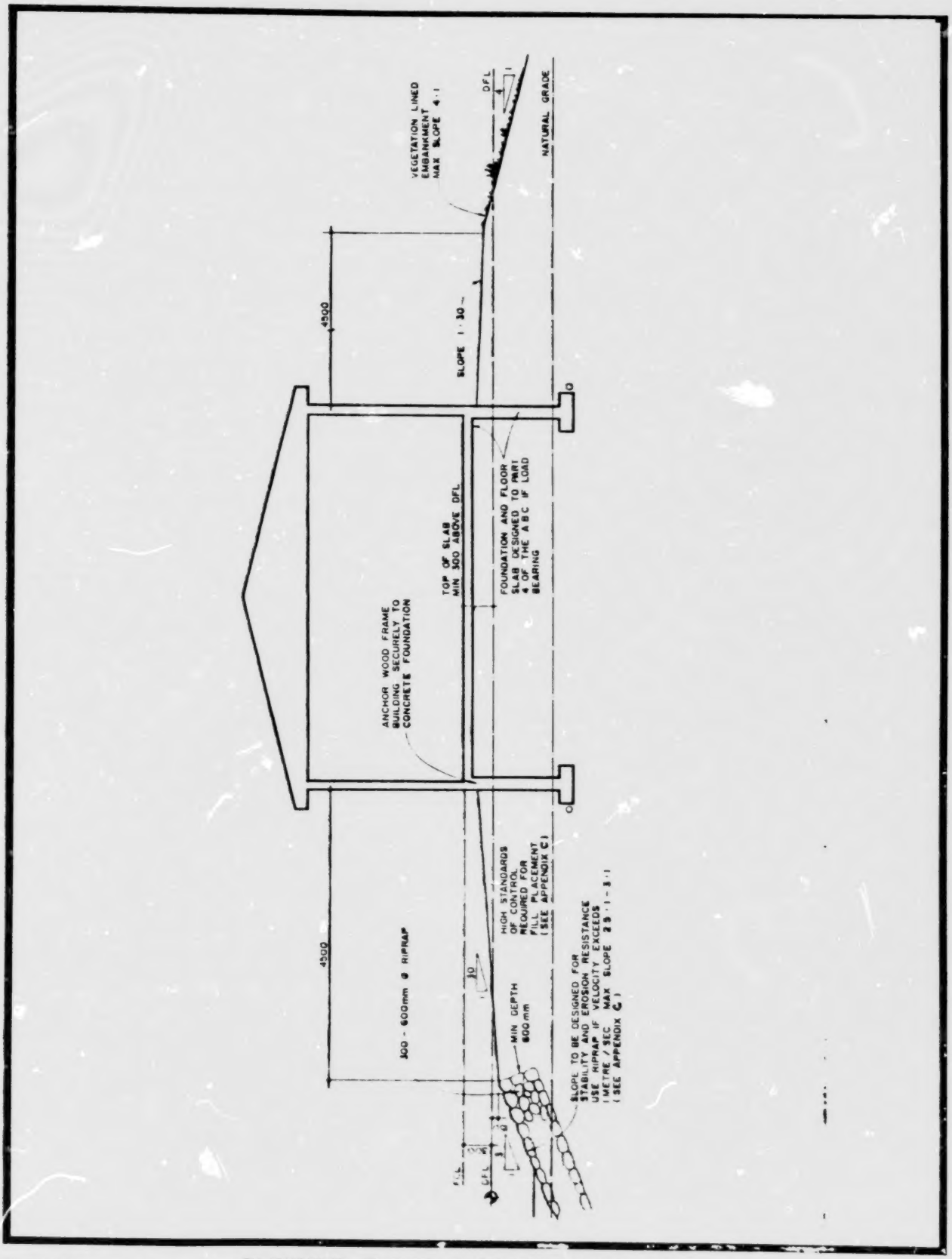

VEGETATION LINED EMBANKMENT MAX SLOPE 4:1
DFL
NATURAL GRADE
4500
SLOPE 1:30
TOP OF SLAB MIN 300 ABOVE DFL
ANCHOR WOOD FRAME BUILDING SECURELY TO CONCRETE FOUNDATION
FOUNDATION AND FLOOR SLAB DESIGNED TO PART 4 OF THE A B C IF LOAD BEARING
4500
300 - 600mm ø RIPRAP
HIGH STANDARDS OF CONTROL REQUIRED FOR FILL PLACEMENT (SEE APPENDIX C)
MIN DEPTH 600 mm
SLOPE TO BE DESIGNED FOR STABILITY AND EROSION RESISTANCE USE RIPRAP IF VELOCITY EXCEEDS 1 METRE / SEC MAX SLOPE 2.5:1 - 3:1 (SEE APPENDIX C)

Figure 16 ELEVATED FLOOR SLAB ON RAISED FILL

The principal advantage of this alternative is that an elevated structure is a passive system, sometimes referred to as "non-contingent", and not dependent on human actions for all flooding conditions up to the design flood level. Even if the design flood level is exceeded, the depth of water over the plateau of fill on which the building is sitting will generally be shallow, and the duration will usually be short.

Additional advantages of raising with fill (as opposed to piles or similar elevated foundations) include its generally traditional Albertan appearance, ease of access to the lowest floor (may be ramped), the ability at many sites to connect the filled area to higher ground for emergency evacuation in a flood, the protection of building elements from deterioration caused by exposure to flood waters, and the thermal insulation the earth provides the bottom of a house. In cold climates, spring flood water under a house elevated on piles can freeze or carry ice debris, with the danger of uplifting the structure.

The major disadvantage to the earth fill system is that significant amounts of material hauled into a flood plain for this purpose may obstruct the natural flow of water or result in a loss in floodwater storage capacity. Either condition can cause higher and more frequent flooding. Before a structure is placed on fill, local land use regulations should be checked to determine if such action is allowed. Such regulations refer to the hydraulic capacity of the floodplain at that point in the stream.

This disadvantage may be eliminated however, if flood plain filling is conducted as part of a pre-determined strategy in the two-zone concept. No construction would take place in the designated floodway. In the United States for example, most two-zone flood plain regulations accept controlled encroachment within the natural 100-year flood lines. The encroachment is limited in extent to that which would cause an increase in water level of one foot or less at upstream reaches. A similar

proposal for a Two-Zone concept in Ontario considers controlled filling in the area between the 100-year flood line and regional storm flood lines (which are usually outside the 100-year line). Alberta has recently adopted a Two-Zone approach, having tested it in the Bow River floodplain study of 1973. While isolated and unplanned filling on a property-by-property basis may lead to hydraulic problems, the application of a controlled method based on the comprehensive type study described above would limit or eliminate this disadvantage completely.

Additional design requirements when considering earth fill include useable space on site since the area taken up by the terracing or slope increases with the height of fill. This is shown graphically in Fiqure 17 below. This affects the location and orientation of an individual dwelling relative to its neighbours and the amount of plateau available for construction above the Flood Construction Level (FCL).

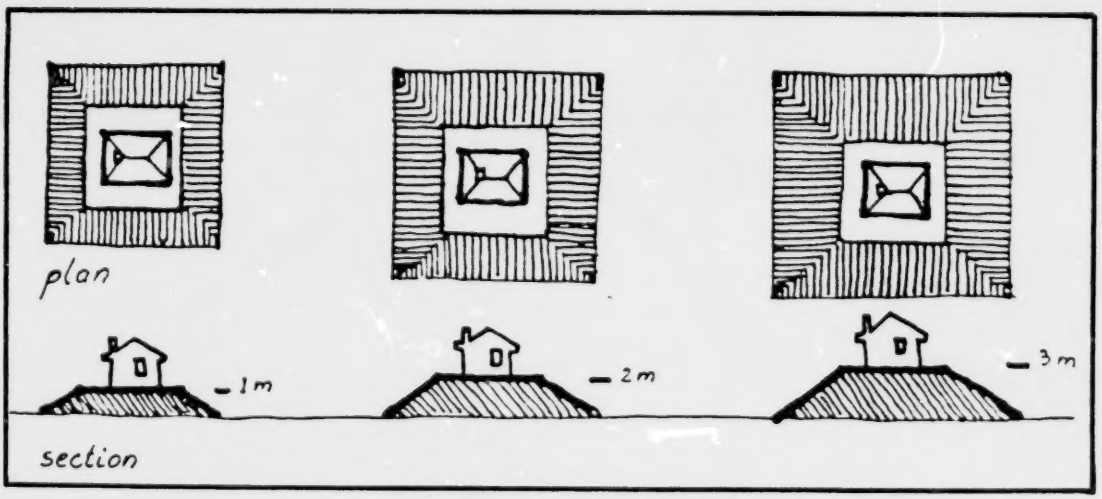


Figure 17 RAISED FILL PLATFORM (reference 27)

However, often in conventional new construction, the site grading in combination with use of a conventional foundation will raise the first floor level sufficiently above the design flood level. In extremely high situations, vehicle access to the dwelling becomes a consideration since a 4 metre wide ramp requires 40 square meters of land for every metre rise at 10% gradient (Figure 18).

Note that ramps require considerable area: a 4 metre wide ramp covers 40 square metres of land for every 1 metre rise at 10% gradient.

Figure 18 **PARKING ACCESS** (reference 27)

For obvious reasons, elevating on fill is a difficult technique for use in infill housing unless the height of the first floor above grade is not excessive and terraces can be used around the building to match adjacent construction. Figure 19 shows some examples of residential buildings that have incorporated this technique.

Section 5.0 provides detailed cost analysis of alternative floodproofing techniques.

The cost of elevating on fill can vary depending on the availability of suitable material, flood depth, soil compaction and scour protection requirements. For a hypothetical 1,000 square foot new house elevated 1 metre above natural grade on protected fill, the extra cost would be around 5% based on the cost analysis shown in Table 3 (page 111). This is reasonably in line with McLaren's 1978 report (reference 20) which projected that the cost of raising a $45,000, 1600 square foot ($149m^2$) house three feet (0.9 metres) above grade on protected fill would be $1,000 to $1,600 or 2-4% of total home cost. By comparison, the cost of elevating an existing structure in this manner is substantially greater at a cost premium of 47% as shown in Table 4 (page 112).

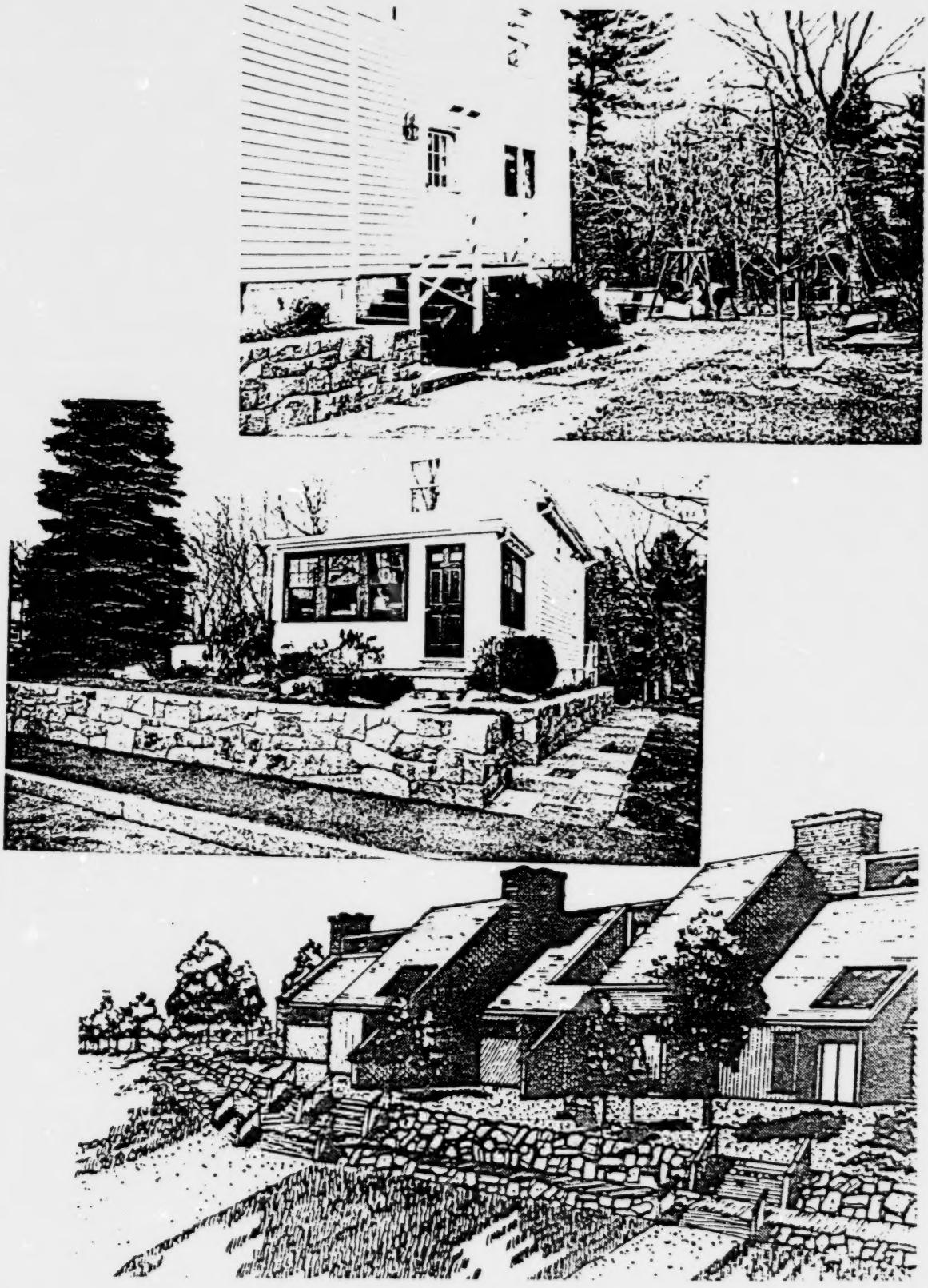


Figure 19 EXAMPLES OF ELEVATION ON FILL

4.3.2 EXTENDED FOUNDATIONS - Continuous Concrete or Block Foundation (Figure 20)

Typically in Alberta, homes are built with basements rather than as a slab on grade. This technique most closely reflects traditional construction in this Province.

Also, In some situations site topography, poor soil conditions, aesthetics, or cost considerations may make it desirable to use an extended masonry or reinforced concrete foundation to elevate a house up to 1.2 metres above natural grade. Using conventional Alberta residential construction techniques of foundation wall and spread footings this would create a basement or crawl space condition which could be bermed with earth fill to provide easy access and a conventional appearance. When complete it would appear similar to the earth fill technique. Alternatively, the lower level can be left exposed to incorporate a garage or other non-habitable basement storage area.

Care must be taken when using extended foundations to prevent differential water pressure from damaging the foundation. One solution is to use high clay content fill because subsurface water flow can be impeded since clay is relatively impervious to water. However this is a tricky solution since expansive clays can put additional swelling pressures on the walls.

If the choice is made to provide a new home with a watertight basement it must be realized that it will require some extra cost to provide the greater strength and waterproofing required.

Residential basements are usually constructed of structural plain concrete, unreinforced masonry block, or grouted reinforced masonry block or reinforced concrete, the latter being the most prevalent in Alberta.

A plain unreinforced concrete wall is typically 200 mm thick without temperature or shrinkage reinforcement. This wall's ability to withstand lateral loads is limited by its tensile strength which varies approximately linearly with compressive strength. Concrete compressive strengths are usually designated as 2,500 psi or 3000 psi for basement walls.

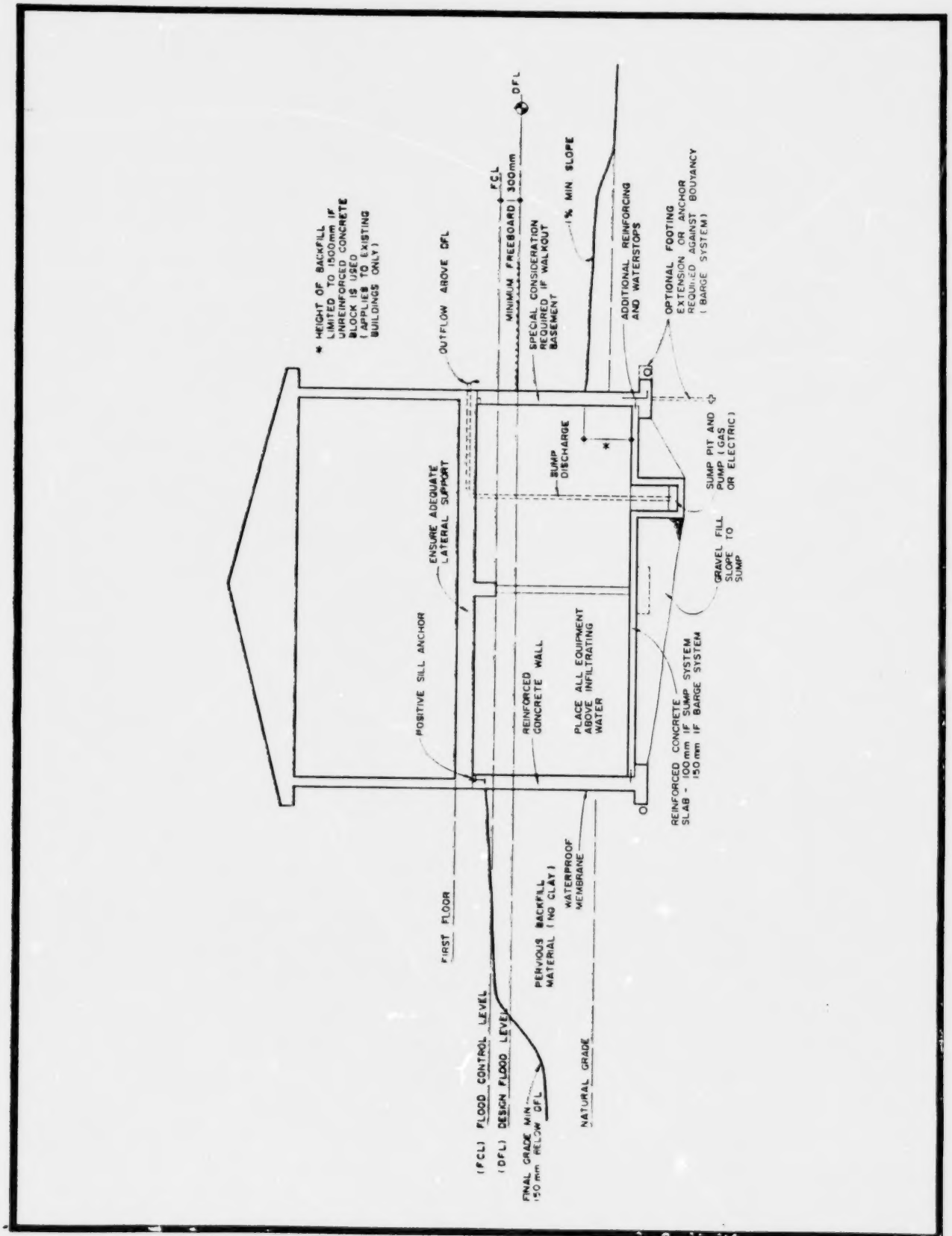

* HEIGHT OF BACKFILL LIMITED TO 1500mm IF UNREINFORCED CONCRETE BLOCK IS USED (APPLIES TO EXISTING BUILDINGS ONLY)
OUTFLOW ABOVE DFL
FCL
MINIMUM FREEBOARD 300mm
DFL
SPECIAL CONSIDERATION REQUIRED IF WALKOUT
1% MIN SLOPE
ADDITIONAL REINFORCING AND WATERSTOPS
OPTIONAL FOOTING EXTENSION OR ANCHOR REQUIRED AGAINST BOUYANCY (BARGE SYSTEM)
SUMP DISCHARGE
SUMP PIT AND PUMP (GAS OR ELECTRIC)
ENSURE ADEQUATE LATERAL SUPPORT
GRAVEL FILL TO SLOPE TO SUMP
POSITIVE SILL ANCHOR
REINFORCED CONCRETE WALL
PLACE ALL EQUIPMENT ABOVE INFILTRATING WATER
REINFORCED CONCRETE SLAB - 100mm IF SUMP SYSTEM 150mm IF BARGE SYSTEM
FIRST FLOOR
PERVIOUS BACKFILL MATERIAL (NO CLAY)
WATERPROOF MEMBRANE
(FCL) FLOOD CONTROL LEVEL
(DFL) DESIGN FLOOD LEVEL
NATURAL GRADE
FINAL GRADE MIN 150 mm BELOW DFL

Figure 20 EXTENDED FOUNDATION WITH WATERTIGHT BASEMENT

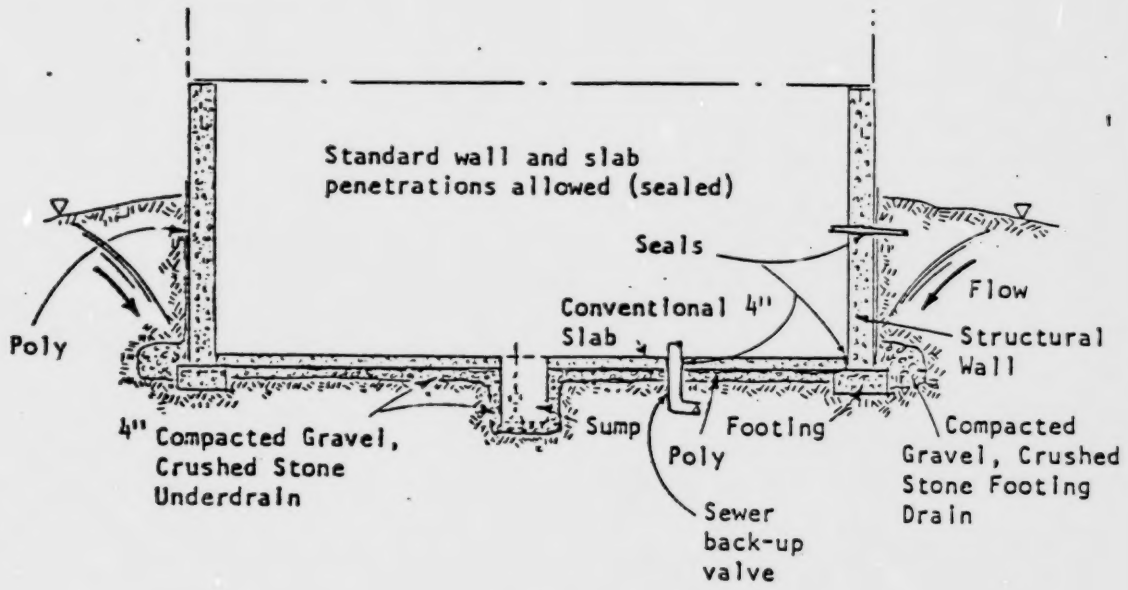
Reinforced cast-in-place concrete walls are also typically 200 mm thick for residential construction but contain both vertical steel bars for load resistance and horizontal steel bars for temperature and shrinkage control. This type of construction is the best method when large lateral loads are anticipated.

Unreinforced masonry block walls are eight or ten inches thick and simply consist of block units set in mortar with no reinforcement. This type of wall should only be used for minimal loading; it is not suitable for large lateral loads.

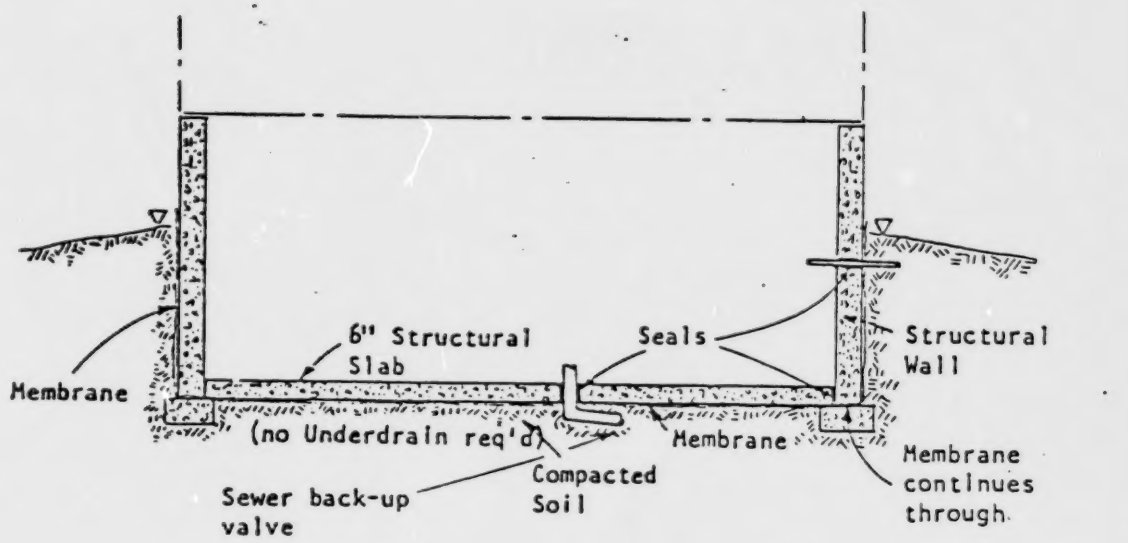
Masonry block walls may be reinforced by adding vertical reinforcing bars which are grouted into the block cavities. Horizontal wire reinforcement may also be added at regular intervals between some of the block courses. This kind of wall can provide the necessary strength for large lateral loads. Masonry foundation walls are more common in Eastern Canada than Alberta.

If the foundation is not specifically designed to withstand lateral loading or if it is not bermed with fill, an alternative design consideration would be the provision of sufficient openings in the foundation to allow the unimpeded flow of flood waters through it. This intentional flooding can be used to balance internal and external water pressures. If the foundation is designed properly, the pressure equalization that results can help minimize both hydrodynamic and hydrostatic forces without affecting its strength. Effectively the result is "wet floodproofing" which will be discussed in section 4.4 as a separate technique. Using potable water for deliberate flooding can minimize cleanup after the flood.

However, if a useable watertight basement is preferred, there are two systems for protecting watertight basements from flood waters - the sump and the barge (Figure 21). The sump system accepts leakage and uses a sump to collect and dispose of infiltrating water. The concept is that any water infiltrating into a reasonably built basement usually can be removed before damage is done. It has the following advantages:



DRAINED OR SUMP SYSTEM



UNDRAINED OR BARGE SYSTEM

Figure 21 EXTENDED FOUNDATION - BASIC WATER TIGHT SYSTEMS (reference 28)

1. controls surface water to minimize the quantity of water impinging on basement surfaces;
2. provides walls and slab built as waterproof as economically feasible;
3. allows any water that would otherwise enter the basement to flow into a sump;
4. reduces the hydrostatic head against the basement wall and slab by allowing water outside the wall and under the slab to flow through a drainage field of crushed stone or gravel into the sump; and
5. removes water from the sump by gravity drainage to a storm sewer or to the ground surface below the slab level if the house is built upon a slope. If gravity drainage is not available, a sump pump will be required. (A sump pump approach requires a continuous source of power during floods.)

Application of the Sump method is limited by the ability of the pump to remove water as fast as the maximum flood waters are inflowing. This requires a balance of pumping capacity with inflow, which is determined primarily by soil permeability. A sump pump approach also requires a continuous source of power during floods.

Although somewhat more costly, the Barge system is more effective than the sump system and is required in locations with conditions beyond the capability of the sump system. The Barge system uses a basement designed to be watertight like the hull of a barge. Basement walls and floor slabs are designed to resist anticipated water and soil pressures. In addition, they are wrapped in a complete waterproofing envelope. It produces the following results:

1. controls surface water to minimize the quantity of water impinging on basement surfaces;
2. provides walls and slab designed and built to withstand the maximum anticipated flood level. This requires good design practice, high quality materials, extra care in placing and curing, adequate reinforcement, and proper supervision;

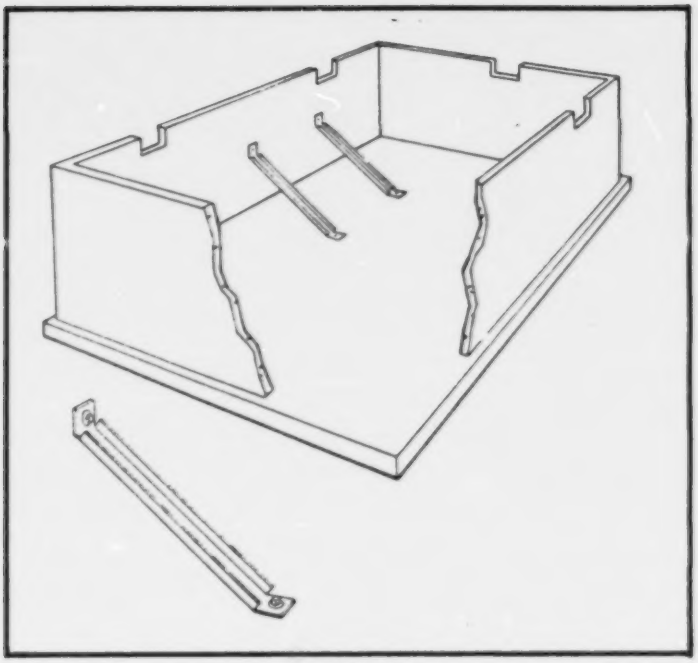
3. encloses the floor slab and walls below grade with a watertight membrane.

Some usable watertight membranes are prefabricated asphalt, asphaltic plastic, butyl rubber or neoprene panels, and elastomeric coatings. Parging, mopped tar, and other inflexible surface coatings cannot accommodate cracks in concrete and therefore do not provide a positive seal. Uncoated concrete of exceptional quality can be made watertight. This, however, requires commercial practice sometimes not used by residential concrete contractors. In addition, concrete admixtures or intercrystalline treatment can provide watertight concrete. If a quality watertight membrane is not used, waterproofed control joints are required to take care of the cracking common to concrete.

In an existing building, one labors under a disadvantage when trying to evaluate the basement structure if the specifications are not available. The quality of concrete is difficult to determine. The presence and location of reinforcing steel in walls and slab may not be known. Other variables such as flood levels and soil permeability complicate evaluating the adequacy of basement structures. Older basements may have been "field tested" by previous years' floods, but the effects of an unusually heavy flood are still unknown.

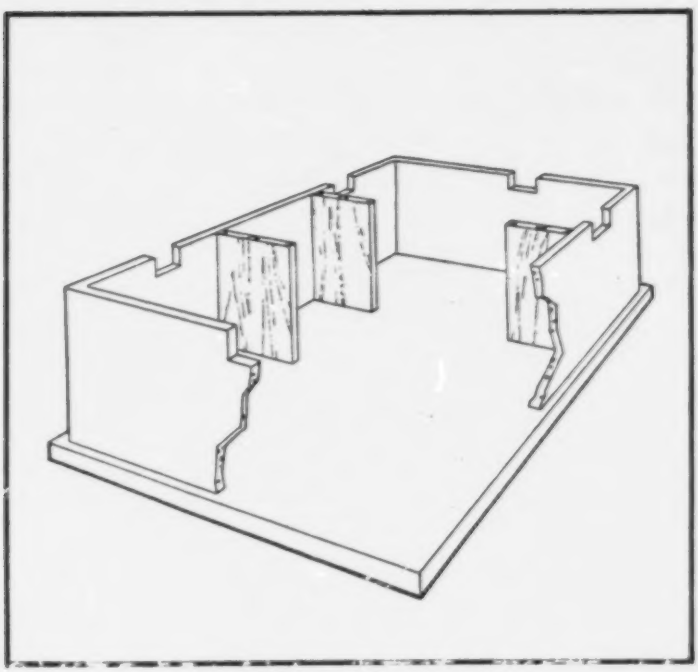
If existing basement walls are of questionable strength to resist flood water build-up, the problem may be reduced in several ways:

1. Allow water to enter basement to equalize water pressure on both sides of basement wall and floor (wet floodproofing).
2. Apply shoring (Figure 22) to help support long spans of basement wall. Shoring may be either emergency, removable, or permanent. Shoring installations should be individually designed by a structural engineer for each basement.
3. Install shear partitions (Figure 23) that intersect and support midspan sections of basement walls and floors. A shear partition is a plywood-sheathed 2x4-framed wall fastened to the basement wall, slab, and floor above. It extends at least 1200 mm (4 feet) in from the basement wall.



SHORING

Figure 22 (reference 24)



SHEAR PARTITIONS

Figure 23 (reference 24)

Pilasters (Figure 24) which are structural wall thickenings, may be designed into new cast concrete or concrete block basements to provide additional lateral support for the walls.

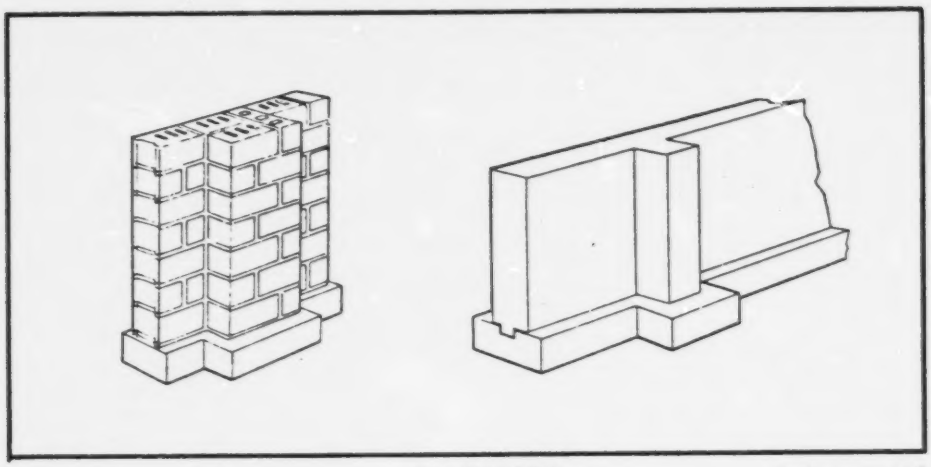
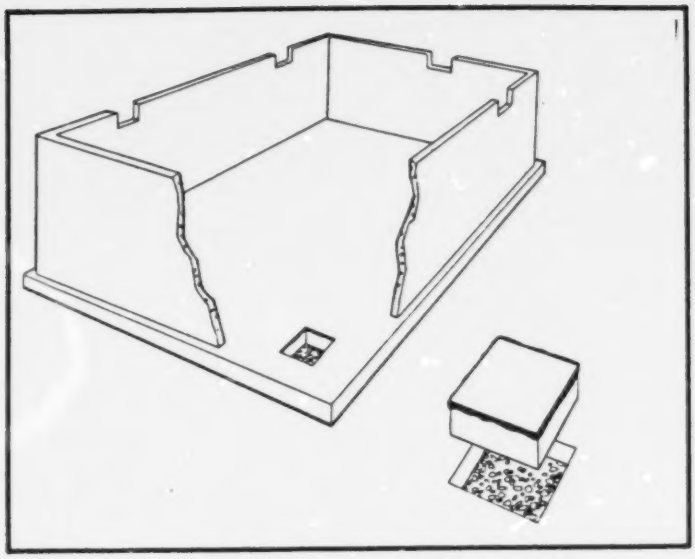


Figure 24 PILASTERS (reference 24)

Basement floors are also subject to variable water pressures during floods. If water were able to migrate down the wall freely and extend across the entire bottom surface of the floor slab, a water level less than a foot above the bottom surface of the slab could rupture a 150 mm (4") thick unreinforced concrete floor. Installing a floor blow-out plug (Figure 25) or a built-in break away wall panel in existing homes may decrease the chance of a slab's structural failure. The need for a blow-out plug should be based upon an engineering evaluation of the chance of failure and should consider soil permeability, basement structure, and anticipated flood levels. In new homes, basement floors may be strengthened during construction by reinforcing, post-tensioning, or using intermediate structural walls designed for floor support (Figure 26), thus eliminating the need for a blow-out plug.



BLOW-OUT PLUG

Figure 25 (reference 24)

Additional considerations are:

1. preventing leakage into basement through foundation joints and cracks by applying waterproof membranes;
2. providing for a sump pump to remove leakage water;
3. providing positive sill anchors to prevent the house being dislocated from the basement foundation;
4. use of water resistant materials; and
5. locating equipment and appliances on pads at least a few inches above basement floor level to raise them above the expected infiltrating water level.

The main advantage of the extended foundation technique is that it is an adaptation of conventional Alberta residential construction practice. Although greater care is required during design and construction, it results in a conventional final appearance which integrates well into existing communities.

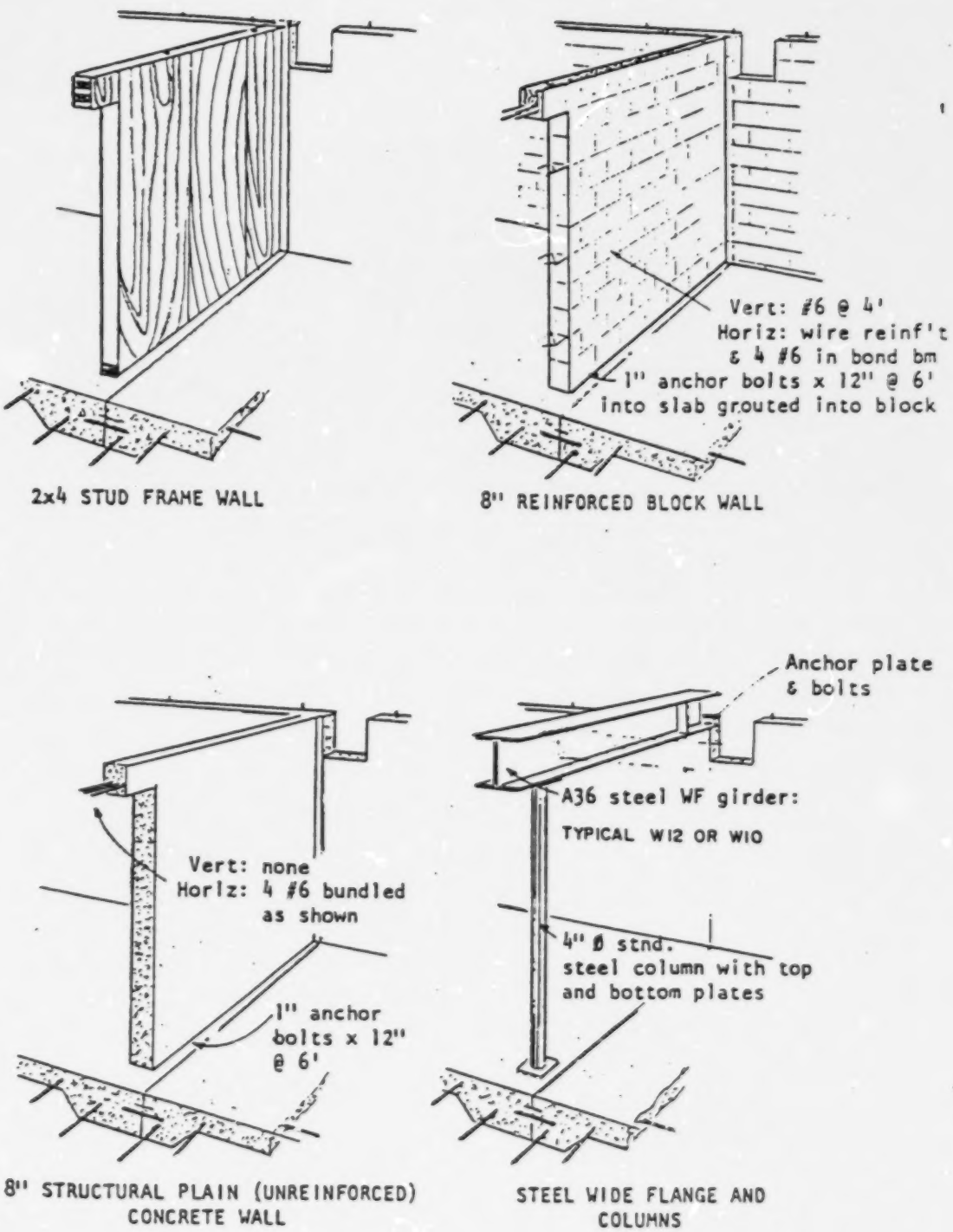


Figure 26 ANTI-BUOYANCY SUPPORT WALLS (reference 26)

For cost comparisons and using the prototypical 1000 sq.ft. residence for this case study, with the Design Flood Level 1 metre above the natural grade, a combination of floodproofing elements were included as indicated in Tables 5 and 6 (pages 113 and 114). The extra cost, using 1987 Edmonton base prices was 6% for the sump system and 10% for the barge system.

The comparable cost for floodproofing an existing building of the same type is described in Tables 7 and 8 (pages 115 and 116) and was estimated to cost an additional 30% for the sump system and 37% for the barge system.

Section 5.0 provides a detailed analysis of these construction costs.

4.3.3 ELEVATION OF STRUCTURE ON COLUMNS - Piers, Piles, Post, Shear Walls (Figure 27)

There are many similarities between this method and raising on fill. The comparative advantage of using columns, piles, piers, or posts is that floodplain water storage is not reduced and upstream flood levels are not usually raised. There is also an additional benefit in that the open area between columns can be used for parking or sheltered access to a building. However, a more detailed approach to the design of the foundation is required since columns are more susceptible to impact from ice and other debris. Debris may also be trapped by the piles or columns causing increased hydrodynamic pressure from the water flow.

Elevation on columns is most suited to small or light structures although concrete shear walls can be used for motels, apartments, cluster housing and other more massive buildings.

Even though the best time to floodproof is obviously during initial construction, elevation is often the most practical alternative for flood proofing existing smaller structures currently sitting on conventional foundations. It is possible to physically lift a building and place it on a newly designed elevated foundation. Small or light buildings can be successfully raised for modest sums, but large or heavy buildings, such as apartments require considerable expense to floodproof.

One disadvantage of elevation on columns is that space under the dwelling is restricted to items or uses which are of low value, easily portable or not damageable by water. Also the elevation of habitable space above the Flood Construction Level (FCL) requires extra space under or beside the dwelling for stairs or a ramp.

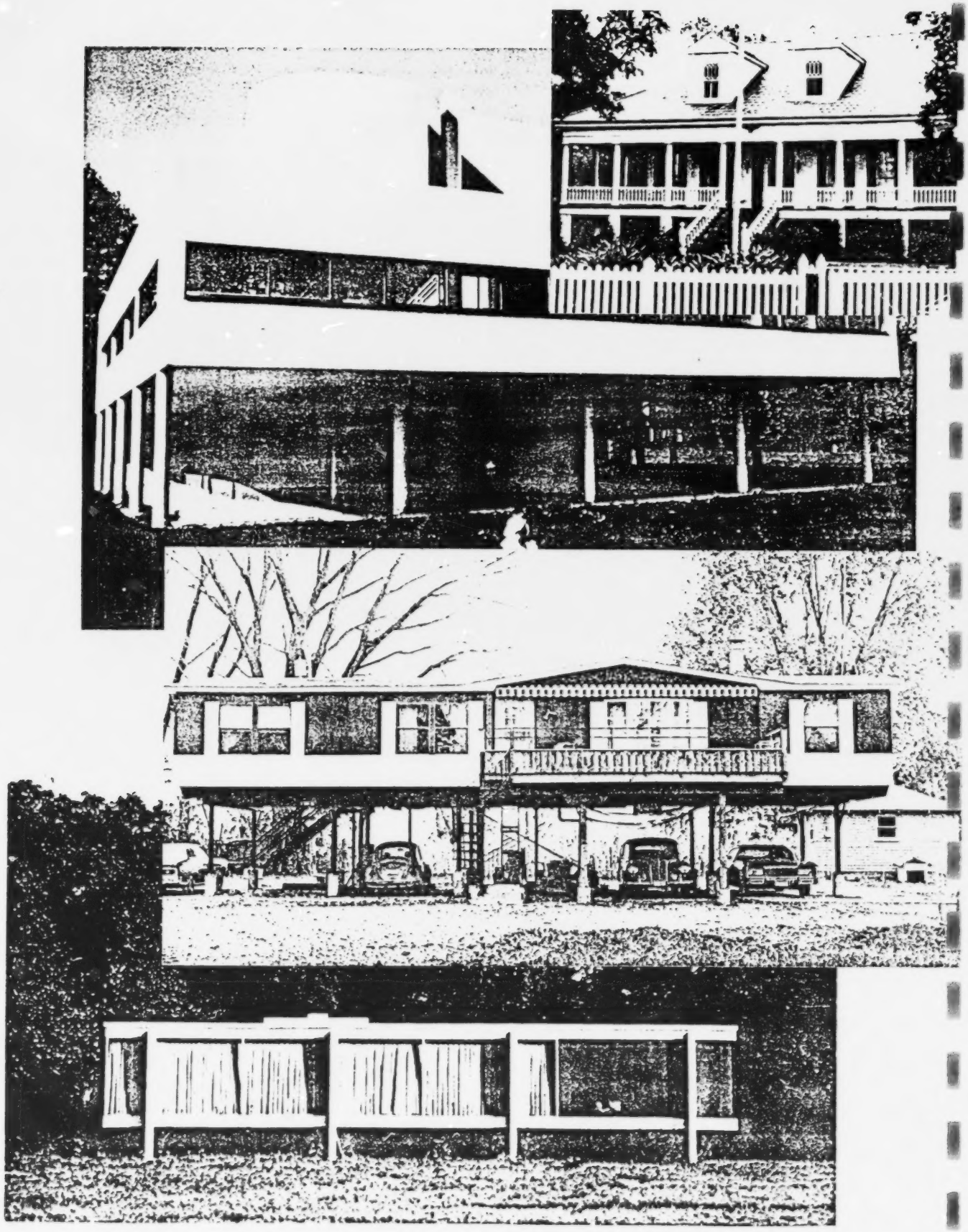


Figure 27 EXAMPLES OF ELEVATION OF STRUCTURE ON COLUMNS

The following general principles apply to the elevation of a home by structural means:

- Space supports a minimum of 2.5 metres apart to allow passage of debris. The supports shall, as far as practicable, be compact and free from unnecessary appendages which would tend to trap or restrict free passage of debris during a flood.
- Orient supports for least resistance to floodwater flow. Solid walls, or walled in columns are permissible if oriented with the longest dimension of the member parallel to the flow.
- Non-structural walls below the FCL and perpendicular to floodwater flow are to be of a breakaway or demountable type or suitably constructed to withstand flood forces.
- Supports shall be capable of resisting all applied loads as required by The Alberta Building Code and all applicable flood related loads as required.
- Bracing, where used to provide lateral stability, shall be of a type that causes the least obstruction to the flow and the least potential for trapping floating debris.
- Foundations for the supports may be of any approved type capable of resisting all applied loads, such as spread footings, mats, piles and similar types. In all cases, the effect of submergence of the soil and additional flood water related loads shall be recognized.
- Choice of post, pier or pile construction will depend on local soil conditions, available technology, and anticipated scour action. The potential of surface scour around the supports shall be recognized and protective measures provided, as required.

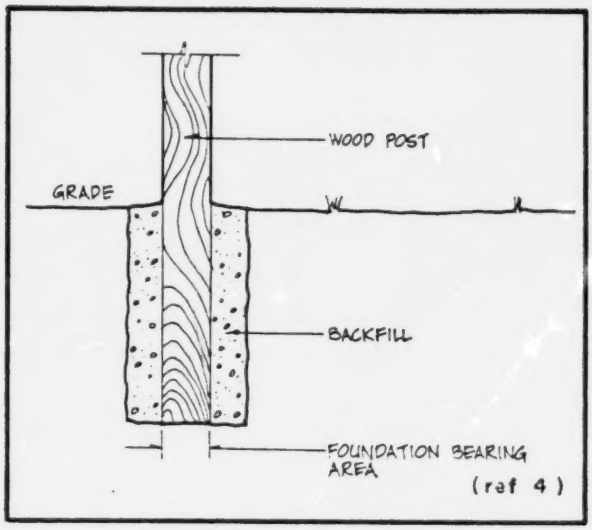
Both posts and piles consist of long slender columns made of wood, steel or concrete. The round, square, or rectangular section is the most common of many available shapes. Posts are set in predrilled or predug holes, generally to a maximum depth of 8', and then backfill is placed in the hole. Using concrete for a portion or all of the backfill will increase stability. Pile supports differ in that they are mechanically driven into the ground. Vertical loads are supported by friction between the pile surface and the soil, and also by the end bearing capacity.

The depth of embedment of posts and piles is determined by soil conditions, anticipated loading and scour, and the spacing and size of the members. Wood posts are generally embedded deep enough to establish required bearing forces. Bearing forces depend on several soil characteristics and determination should be done using standard soil engineering procedures.

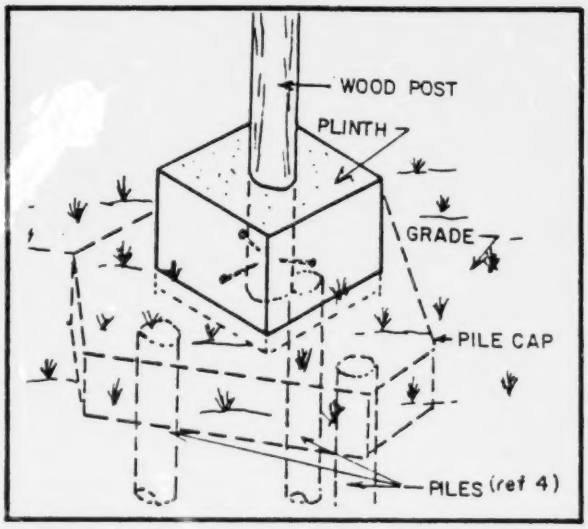
For large loads and/or poor soil conditions, a concrete pad should be placed in the bottom of the hole. This increases the bearing area and capacity. For very poor soil, it may be necessary to use a group of piles and a pile cap to support each post.

Possible backfill material includes sand, gravel, crushed rock, soil cement, concrete, and earth. Soil cement can attain strength nearly equal to concrete and is made by mixing earth with cement in a 5:1 ratio (earth:cement). All organic matter should be removed from the soil prior to mixing. If an earthen fill is used, it should provide good drainage away from the posts or piles so that deterioration is minimized.

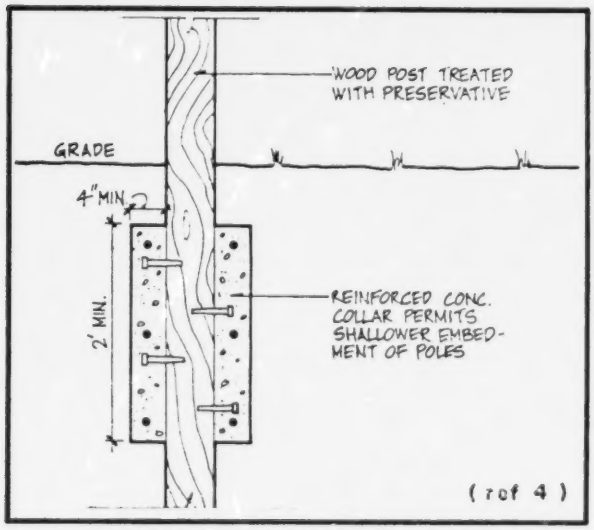
By anchoring the posts, more resistance to overturning and uplift will be provided. A properly designed pile support will have sufficient frictional capacity such that added anchoring is not needed. Posts may be anchored by either embedding them in concrete or fastening them to metal pieces which are embedded in concrete. Figure 28 shows examples of post foundations.



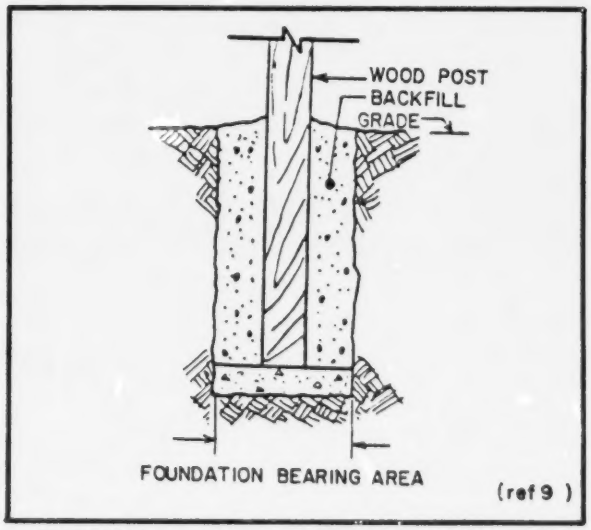
EARTH BEARING



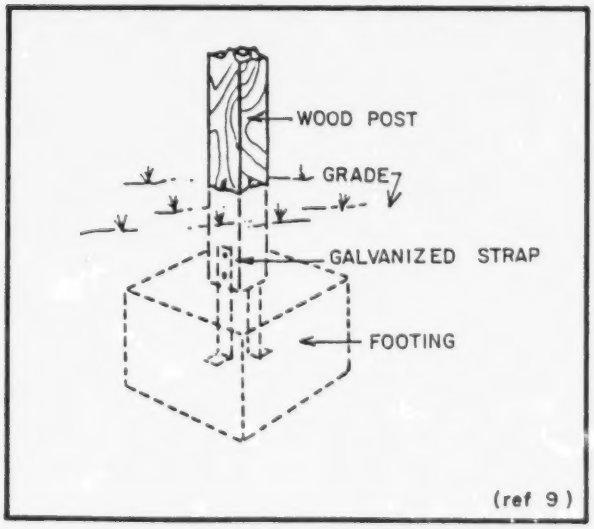
POST ON PILES FOR POOR SOIL



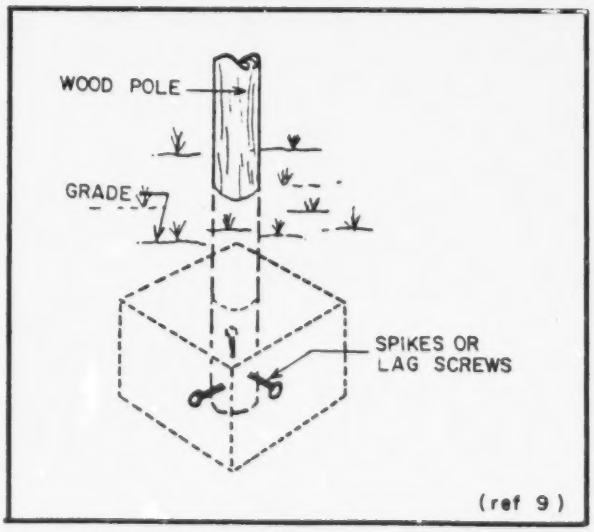
REINFORCED CONCRETE COLLAR



CONCRETE PAD · INCREASED BEARING



POST ANCHORED TO CONCRETE



POST ANCHORED TO CONCRETE

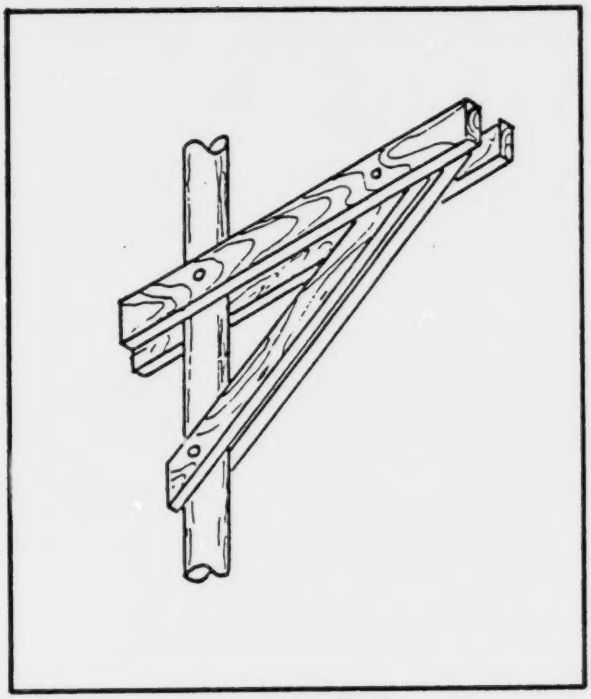
Figure 28 EXAMPLES OF POST FOUNDATIONS

If a post or pile system is to be capable of resisting the expected lateral loads on its own, permanent bracing must be added. Two of the several methods are: the knee brace consisting of 2" by 6" lumber nailed or bolted between the floor joist and post or pile, and cross bracing which is similar but extends from the top of one post or pile to the bottom of the adjacent one. Such bracing should be in a plane parallel with the flood flow for the least obstruction, and least potential for trapping debris, and most efficient use of material. Figures 29 and 30 show additional foundation and bracing details.

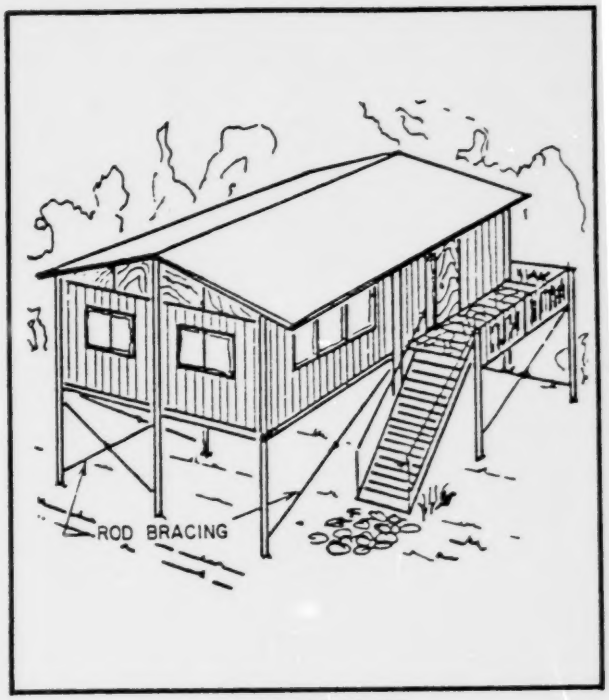
Shear walls, although more commonly used for motels, apartments, and other more massive structures, can also be used to elevate smaller residential structures.

A shear wall acts as a deep beam in resisting forces in the plane of the wall. Structurally, the most critical design consideration is the low resistance of a shear wall to lateral forces. Shear walls should thus be used only in areas subject to low to moderate velocity flooding and should be placed parallel to the expected flow of flood waters. It is important that load and impact forces be determined for the entire range of flow directions. In addition, a shear wall's vulnerability to lateral forces makes it critical that connections between the wall and the foundation elements below grade be well designed.

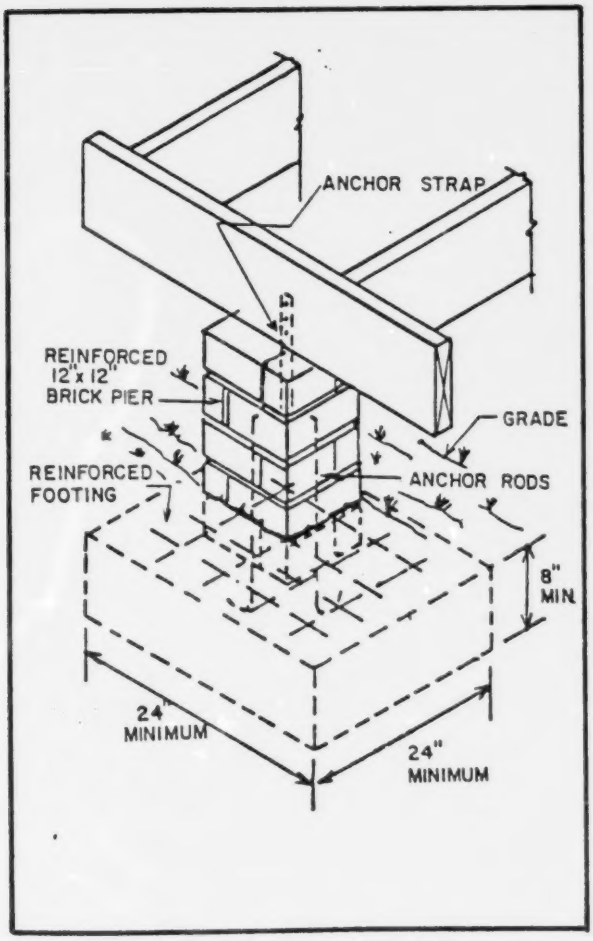
James F. McLaren's 1978 study indicated that the cost of elevating a 1500 square foot (139 square metres) home 7.5 feet (2.3 metres) above grade with wood piles (least expensive), wood posts, or concrete piers (most expensive) increased the construction cost of the home by 8 to 10% over the cost of the same home on a slab-on-grade foundation, and 5 to 7% over a crawl space foundation. (The benefits from extra usable land beneath the structure are not included in calculation of these costs.)



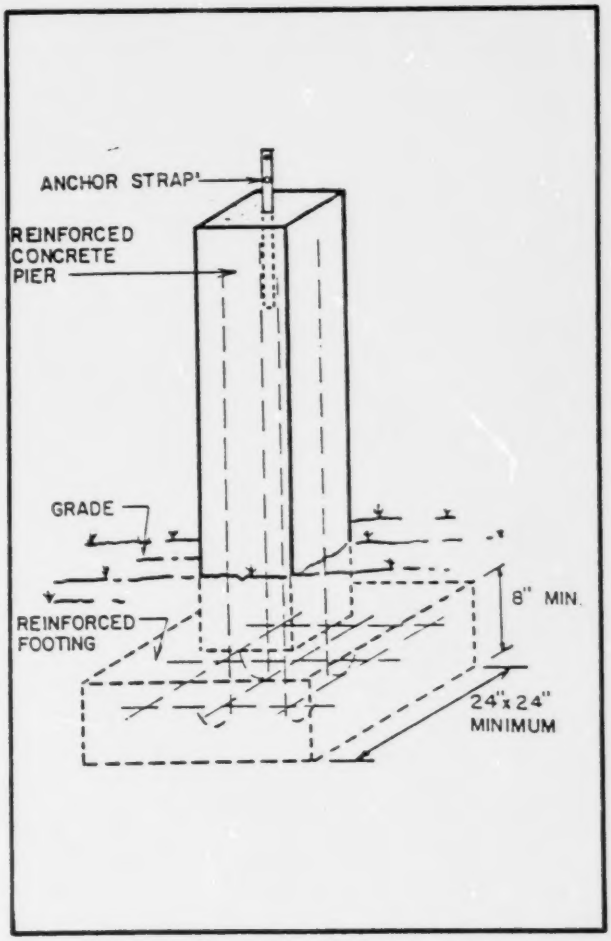
KNEE BRACING



CROSS-BRACING

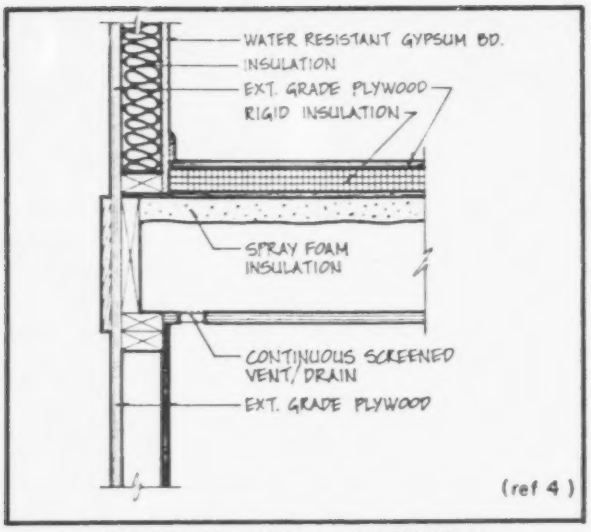


PIER TO FOOTING TIE

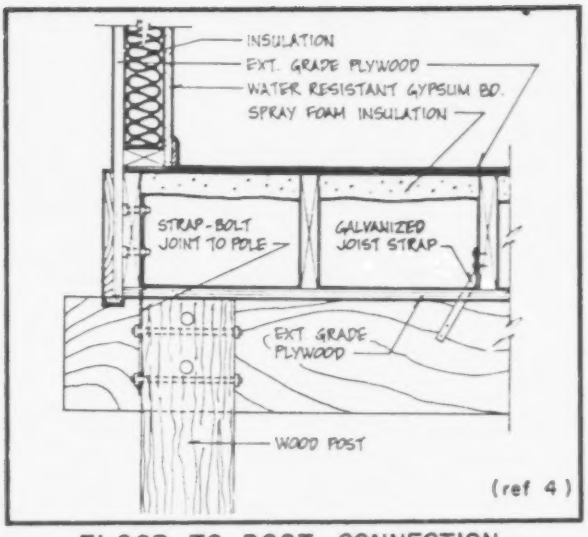


COLUMN TO FOOTING TIE

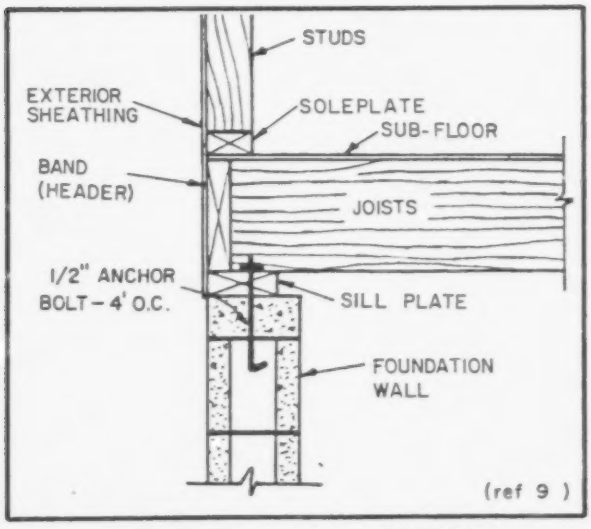
Figure 29 FOUNDATION and BRACING DETAILS (reference 9)



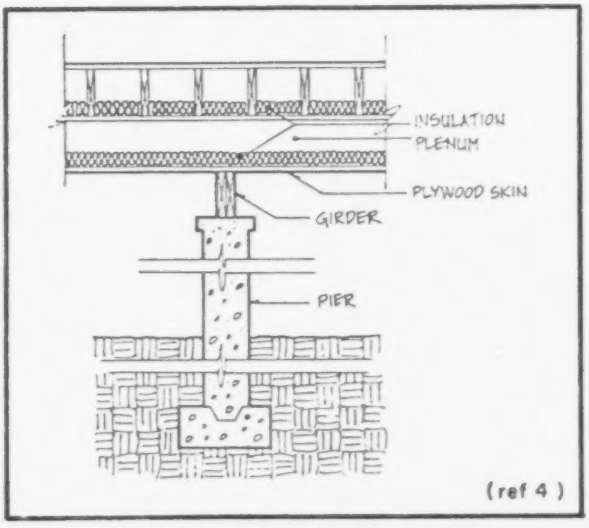
FLOOR TO WALL ASSEMBLY



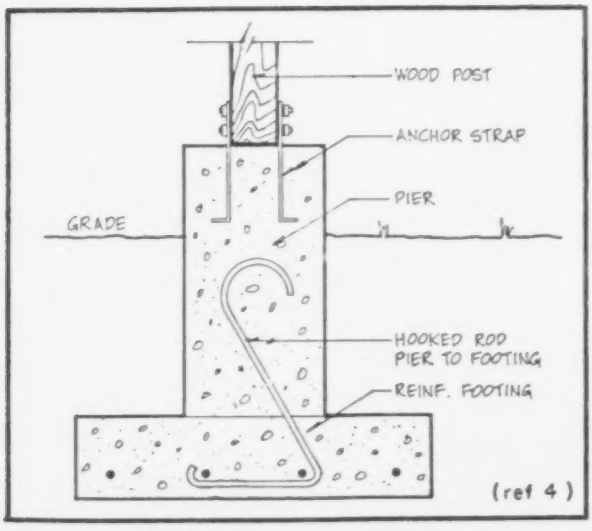
FLOOR TO POST CONNECTION



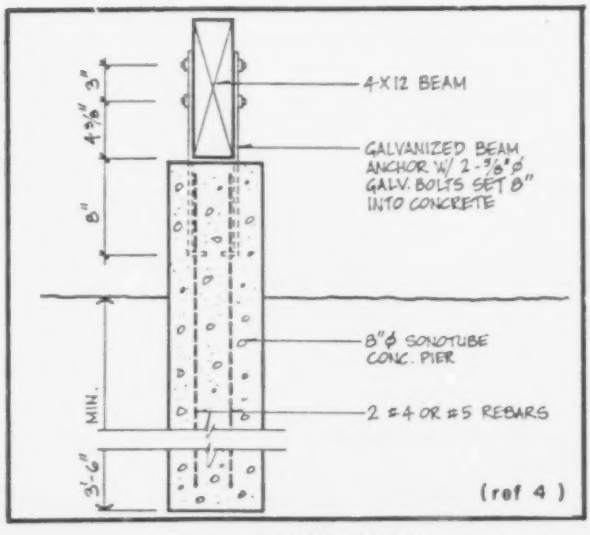
TYPICAL SILL ASSEMBLY



DOUBLE INSULATED FLOOR



POST/PIER FOUNDATION



PILE FOUNDATION

Figure 30

DETAILS

McLaren's study also noted that full basement foundations represent approximately 12.5% of the construction cost of a home. If, in the floodplain, the basement is simply eliminated and the home is raised by the means described above, then generally the total cost of the home will be reduced by 3%. However, if the cost of redistribution of the basement space into a larger area above the FCL is taken into account, then elevating the house by extending foundation walls to a height of 4 feet (1.3 metres) for example, increases the cost of the home by 8%.

Using the prototypical 1000 s.f. house for this study, the additional cost of elevating a new structure on wood piles is 6% as outlined in Table 9 (page 117). The cost of elevating an existing wood frame structure would be 19% as shown in Table 10 (page 118).

4.3.4 FLOODWALLS AND LEVEES - Berms or Dikes (Figure 31)

Levees or floodwalls may be built around both individual buildings or subdivisions. The condition, type or size of the building, all of which were important considerations in previous alternatives are not as critical here since the protective barrier is separate from the main buildings. The controlling factor in the design is the soil condition at the site. Impervious soil is preferred in order to reduce the below grade water infiltration that inevitably occurs. Six feet seems to be the practical height limit for small flood walls and levees.

Floodwalls

The purpose of floodwalls is similar to that of levees - to keep water out of an area. They have the advantage of being able to protect the surrounding site as well as the building itself. They are subject to hydraulic loading on one side. Cellular walls, buttress walls, and gravity walls are some of the different kinds of floodwalls shown on page 74 (Figure 32). Possible modes of failure for floodwalls are overturning, sliding, or failure or underlying soil. If competent rock formations are present, the floodwall should be keyed into the rock for extra protection against failure.

This method of floodproofing is of particular benefit to retrofit or existing situations. Floodwalls are often added after existing buildings or properties have experienced flooding one or more times and generally are used where space or other considerations preclude the use of community levees. If designed properly, floodwalls are effective because they require little maintenance and can be easily inspected. The main problems with this method are keeping closure materials accessible and in good operating order and training personnel to assure timely closure. Generally, floodwalls are constructed from concrete or concrete blocks and have one or more passageways that are closed by gates. Occasionally, a structure will have a floodwall incorporated into the architectural design.

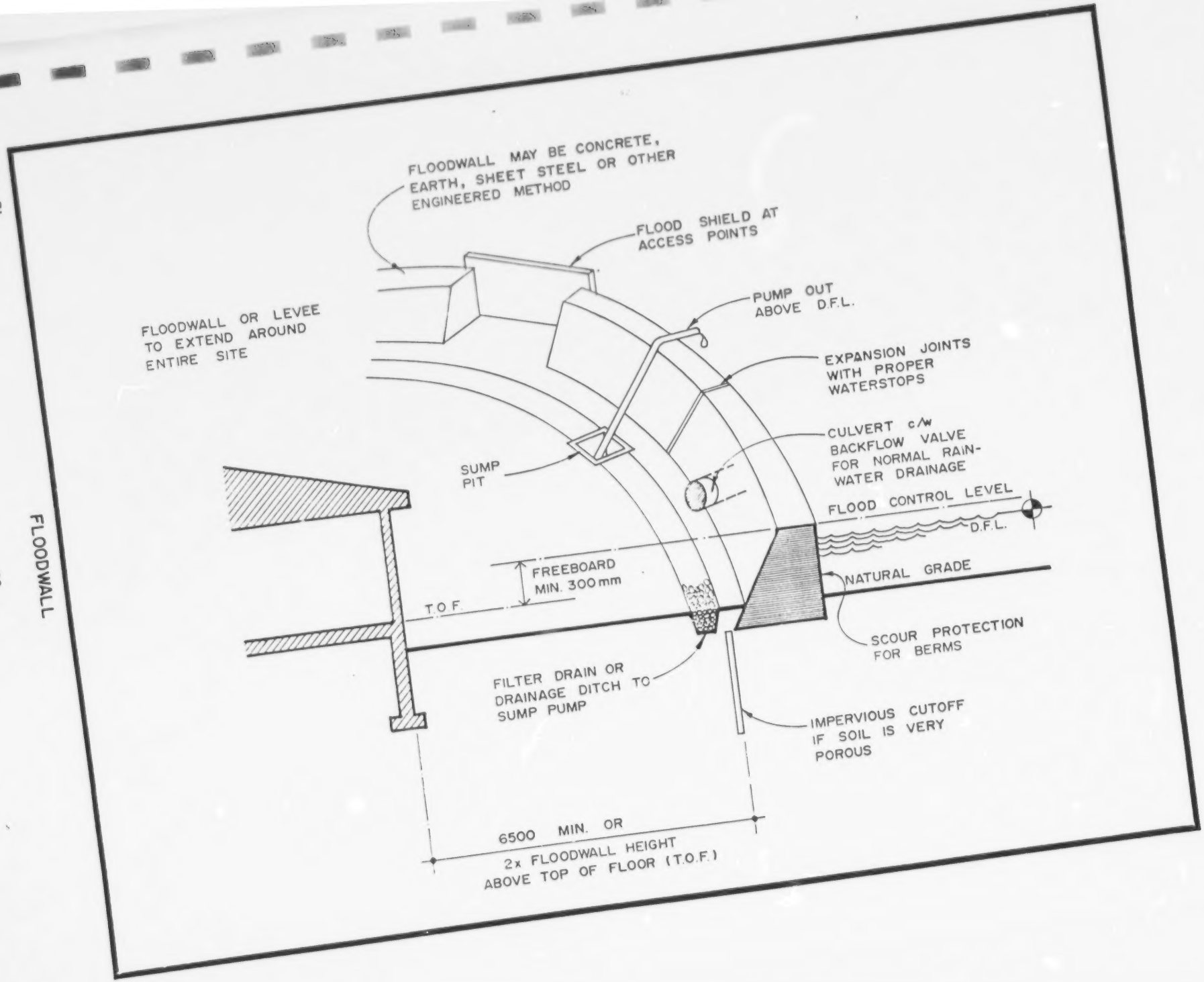

FLOODWALL MAY BE CONCRETE, EARTH, SHEET STEEL OR OTHER ENGINEERED METHOD
FLOOD SHIELD AT ACCESS POINTS
PUMP OUT ABOVE D.F.L.
FLOODWALL OR LEVEE TO EXTEND AROUND ENTIRE SITE
EXPANSION JOINTS WITH PROPER WATERSTOPS
CULVERT c/w BACKFLOW VALVE FOR NORMAL RAIN-WATER DRAINAGE
SUMP PIT
FLOOD CONTROL LEVEL
D.F.L.
FREEBOARD MIN. 300mm
NATURAL GRADE
T.O.F.
SCOUR PROTECTION FOR BERMS
FILTER DRAIN OR DRAINAGE DITCH TO SUMP PUMP
IMPERVIOUS CUTOFF IF SOIL IS VERY POROUS
6500 MIN. OR
2x FLOODWALL HEIGHT
ABOVE TOP OF FLOOR (T.O.F.)

Figure 31

FLOODWALL

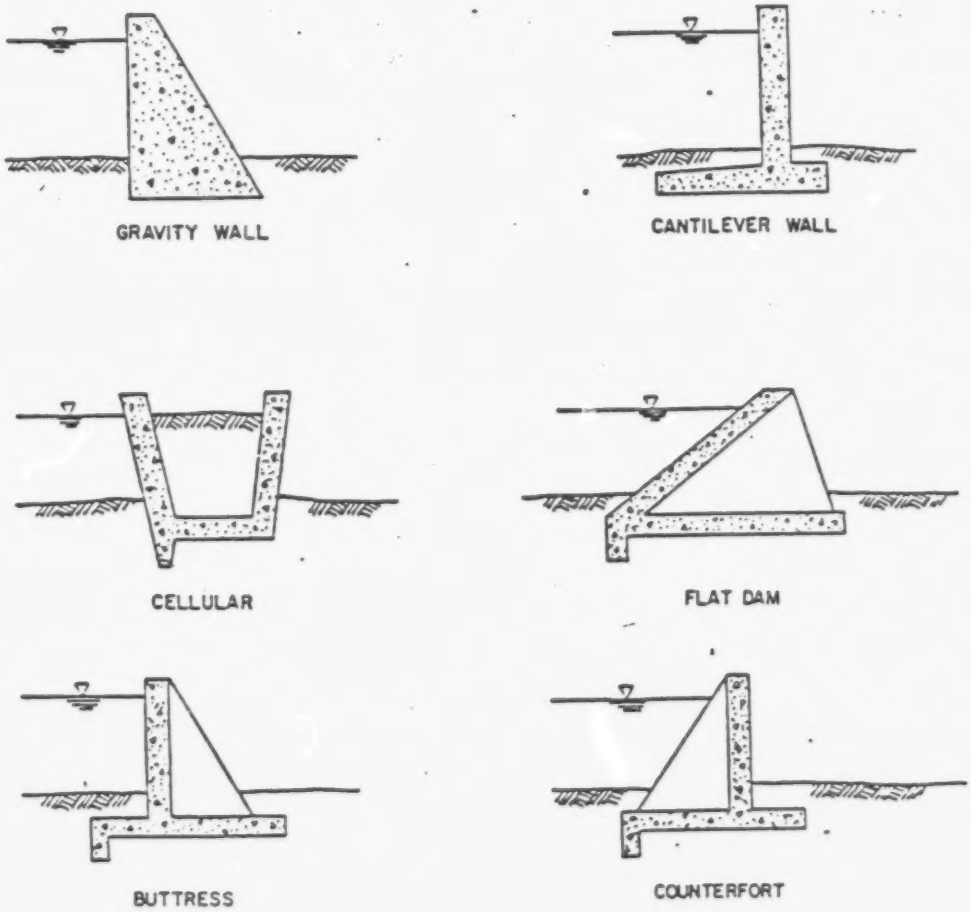


Figure 32 FLOODWALL TYPES (reference 9)

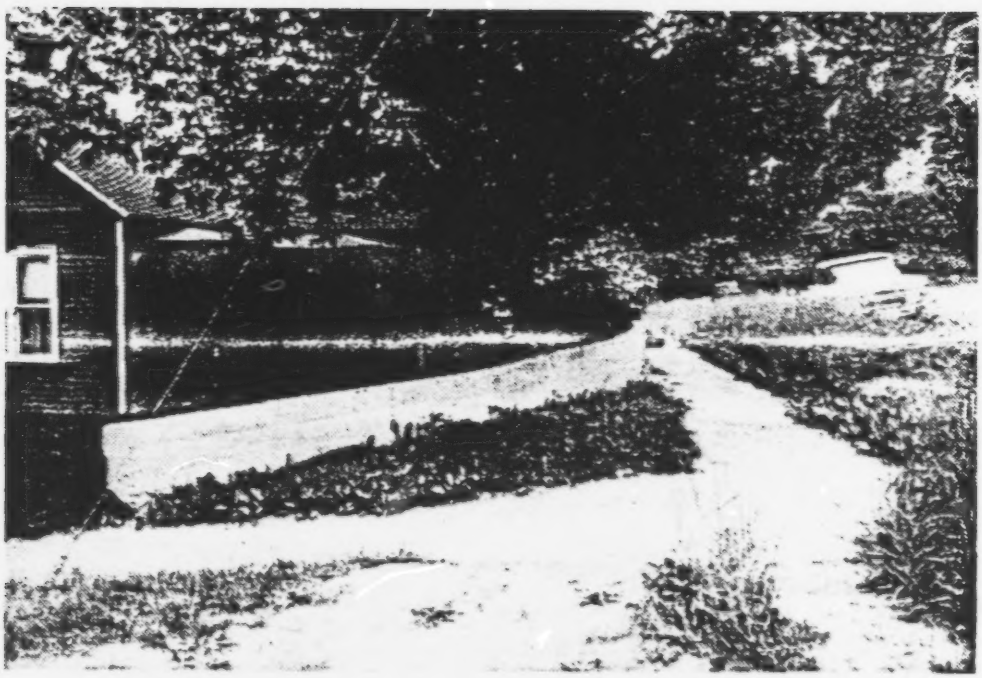
Levees or Ring Dikes (Figure 33)

In some locations, it may be economically unfeasible to adequately floodproof each structure near a river. In such areas, a levee system around an entire block, subdivision or neighbourhood may be the best means of protection from floodwaters. Levees are embankments which prevent a flood from reaching a structure or land area. Neighbourhood levees have been used extensively in the Red River Valley towns of Manitoba. Some homes in South Winnipeg have also been protected this way. The fill that is used must be capable of resisting the imposed loads after it is properly placed and compacted. Local levees generally protect against more frequent lower level food events; however, they can be overtopped during higher floods. The failure of levees protecting larger residential areas can result in even greater losses. It should be noted that a large number of levees with a small floodplain can displace sufficient water to effectively raise the design flood level. This factor must be considered within the overall flood plain management guidelines.

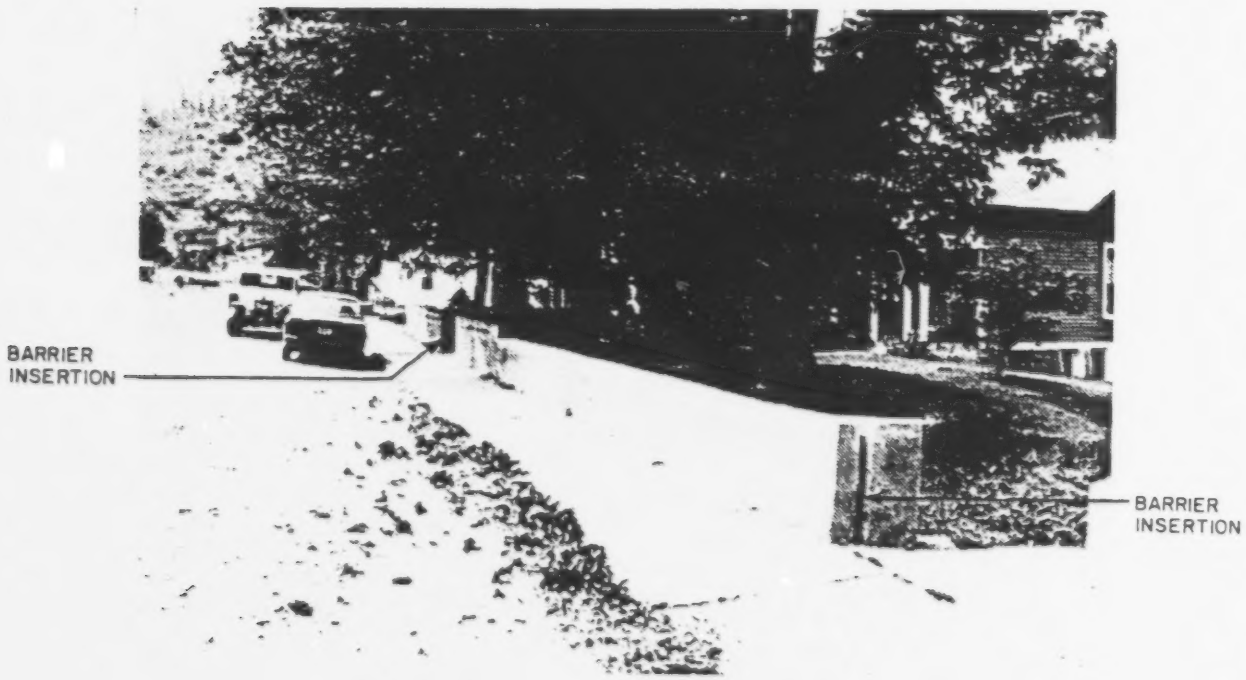
Factors that must be investigated when constructing a levee are slope stability and erosion effects. The site will require soil testing and determination of water forces and velocities. The availability of suitable fill material is another important concern. The fill area should be at or near the construction site, and the material should be tested before it is approved for use. Foundation material must also be tested to determine what subsurface seepage will occur and what drainage control measures, should be used.

An important factor to note about floodwalls and levees is that they are usually dependent on flood warning and require installation of some kind of flood shields or watertight gates at access points.

The use of both levees and floodwalls will usually require a sump pump system to evacuate internal drainage along with underseepage that might occur. Excessive underseepage from improper design or very pervious soil is a common problem. Cutoffs and drains should



Concrete floodwall diverts flow around house, Ouray, CO.



Floodwalls equipped to accept barriers across openings. Ouray, CO..

Figure 33 FLOODWALL EXAMPLES (reference 9)

be provided to carry away any water that has infiltrated into the area and direct it to the sump should not lessen the design for uplift pressures. Also, drain pipes should not be placed directly under the base of a floodwall.

Gravity wall designs are most appropriate for low, lightly loaded floodwalls. They are easy to design and construct, but the large volume of concrete required to provide protection for large heads of water can become a prohibitive cost factor. The cantilever wall is a more complex design, but requires much less concrete. It is suitable for many situations, especially where a moderately high wall is needed. The cantilever wall's base may be supported on drilled piers or piles if soil conditions are very poor. A final point in the design of levees and floodwalls is that the freeboard requirement will vary depending on whether a single structure is being protected or a large area of a community. It could vary from 300 mm to 1 metre of height above the DFL.

Local levees and floodwalls sometimes fail without being overtopped because of poor design, improper material or construction practices, poor maintenance, inadequate pumping facilities, and related reasons; consequently, it is necessary that the design and construction of these structures should only be done with experienced professional engineering direction. In addition, levees protecting larger areas can engender a false sense of security for the residents within.

The cost of providing a floodwall will vary considerably depending on design and localized conditions. However, assuming a wall as shown in Figure 31 extending around a house for a length of 100 metres, Table 11 (page 119) summarizes a cost which can be applied both new and retrofit construction.

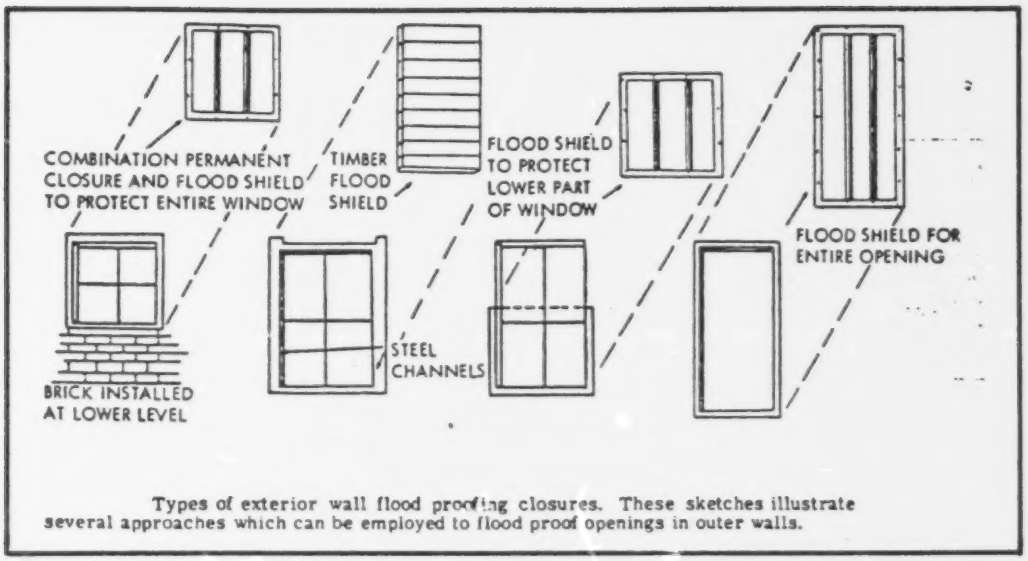
4.3.5 CLOSURES AND SEALS (Figure 34)

The most vulnerable components of the basic building fabric are the points where walls below flood levels are penetrated. These points include doors and windows, as well as utility inlets and, in some cases, underground tunnels to adjacent buildings. Such points should be either located above flood levels or thoroughly waterproofed.

Ideally, all doors and windows should be above the Design Flood Level, with access provided via ramps, stairs, or fill. Rubber gaskets can sometimes be used to seal openings below the base flood elevation, and waterproof conduits can be used to protect utility lines.

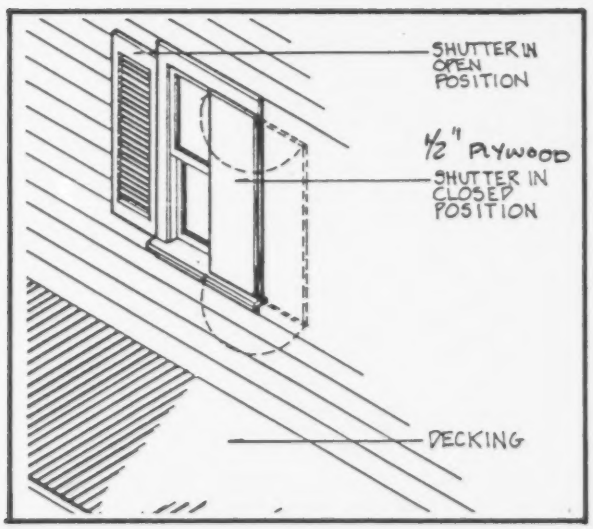
Openings for doors and windows unavoidably located below flood levels can be protected by flood shields which would be put in place upon receipt of flood warnings. These shields can cover openings ranging from small areas to large display windows. They can sometimes be incorporated in the building's structure, out of the way when not needed and, using hinges and rollers, put in place when necessary. They can also be separate from the structure and stored when not in use. Adequate warning time is a prerequisite to the effectiveness of shields.

Closure of openings, as a floodproofing method, is most applicable to structures that meet certain criteria. First, the wall of the structure should be brick, brick veneer, concrete, cement block, stone, or other relatively impermeable materials. The structure should have a small number of openings, unless low outdoor walls are the floodproofing method to be used. Another mandate is that the walls themselves have the structural strength to resist the water forces up to the top of the closures. Finally, the structure should have a sump pump that can take care of seepage during the flood.


COMBINATION PERMANENT CLOSURE AND FLOOD SHIELD TO PROTECT ENTIRE WINDOW
TIMBER FLOOD SHIELD
FLOOD SHIELD TO PROTECT LOWER PART OF WINDOW
FLOOD SHIELD FOR ENTIRE OPENING
BRICK INSTALLED AT LOWER LEVEL
STEEL CHANNELS

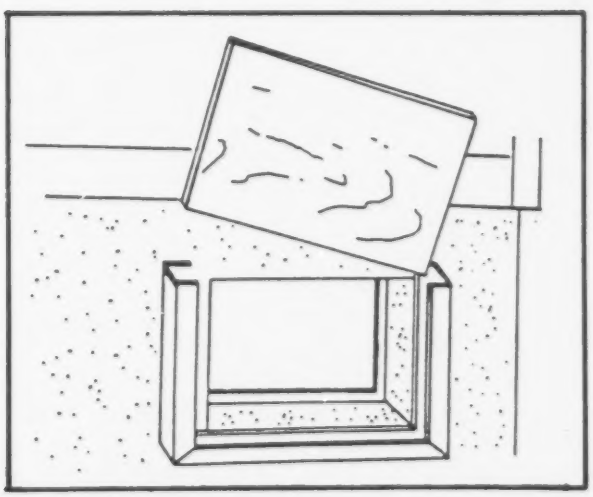
Types of exterior wall flood proofing closures. These sketches illustrate several approaches which can be employed to flood proof openings in outer walls.

(reference 9)



WINDOW SHUTTERS

(reference 4)



REMOVABLE COVER PLATE

(reference 24)

Figure 34 SEALS and CLOSURES

There have been many failures of these systems resulting from poor design practices. Studies have shown that a brick veneer, slab-on-grade home can resist flooding to a depth of two feet before the walls will crack and allow water to enter the building. Most existing residential structures are simply not strong enough to withstand floodwater pressures. Although new residential structures can be reinforced to withstand higher flooding depths, careful design of drainage systems, floor slabs, basement walls and all doors and windows is essential. Closures and seals are generally more suited to apartment or commercial structures of steel, reinforced concrete, reinforced block or brick which are usually more massive than small residential buildings and have more buoyancy resistance.

However, some closure techniques can be used in houses with a certain degree of effectiveness.

In order to provide a watertight closure to a building opening, a variety of bulkhead designs can be used ranging from single plywood sheets to expensive commercially fabricated steel stoplogs. In fact, any durable materials that can withstand the design flood loads may be used. Aluminum is often the best choice because it has the necessary strength, is usually readily available, and its relatively light weight permits easy and quick installation. However, no attempts should be made to seal a structure against floods deeper than 2 to 3 feet until the structure has been examined by a qualified professional engineer to determine that it can withstand the increased hydrostatic loads.

Shields are usually attached to a metal frame for the most reliable connection to the wall. The frame must be capable of evenly transferring the panel loading into the wall. If the frame brackets are an appearance problem, it may be desirable to have a removable trim covering for the frame. Shields may be set on hinges, slide track rollers, or vertical pulley systems. In some circumstances appearance may require that they be stored away from where they will be used.

In order to assure complete watertightness, gaskets or other types of seals must be used between contact surfaces of the shield and frame. Seals should be of the pressure type and permanetly attached to either the frame or the shield. Inflatable seals are available through some manufacturers.

Another consideration is the type of latching device to be used on the shield. Standard bolts, T-bolts, latching dogs, wedge assemblies, or other means may be used as shown in Figure 35.

Whether the shield is put on the outside or inside of the opening will depend on the user and each situation. The advantage of putting the shield on the outside is that the water pressure will help create a tighter seal between the shield and frame to which it is attached. On the other hand, a shield on the inside will probably be more accessible for placement and correction of any problems.

Closure devices should be inspected annually and maintained to preserve structural and waterproof qualities. To improve the effectiveness of this type of floodproofing measure, it is recommended that an operations plan similar to a residential fire prevention drill be developed and followed. The plan should include, the following considerations:

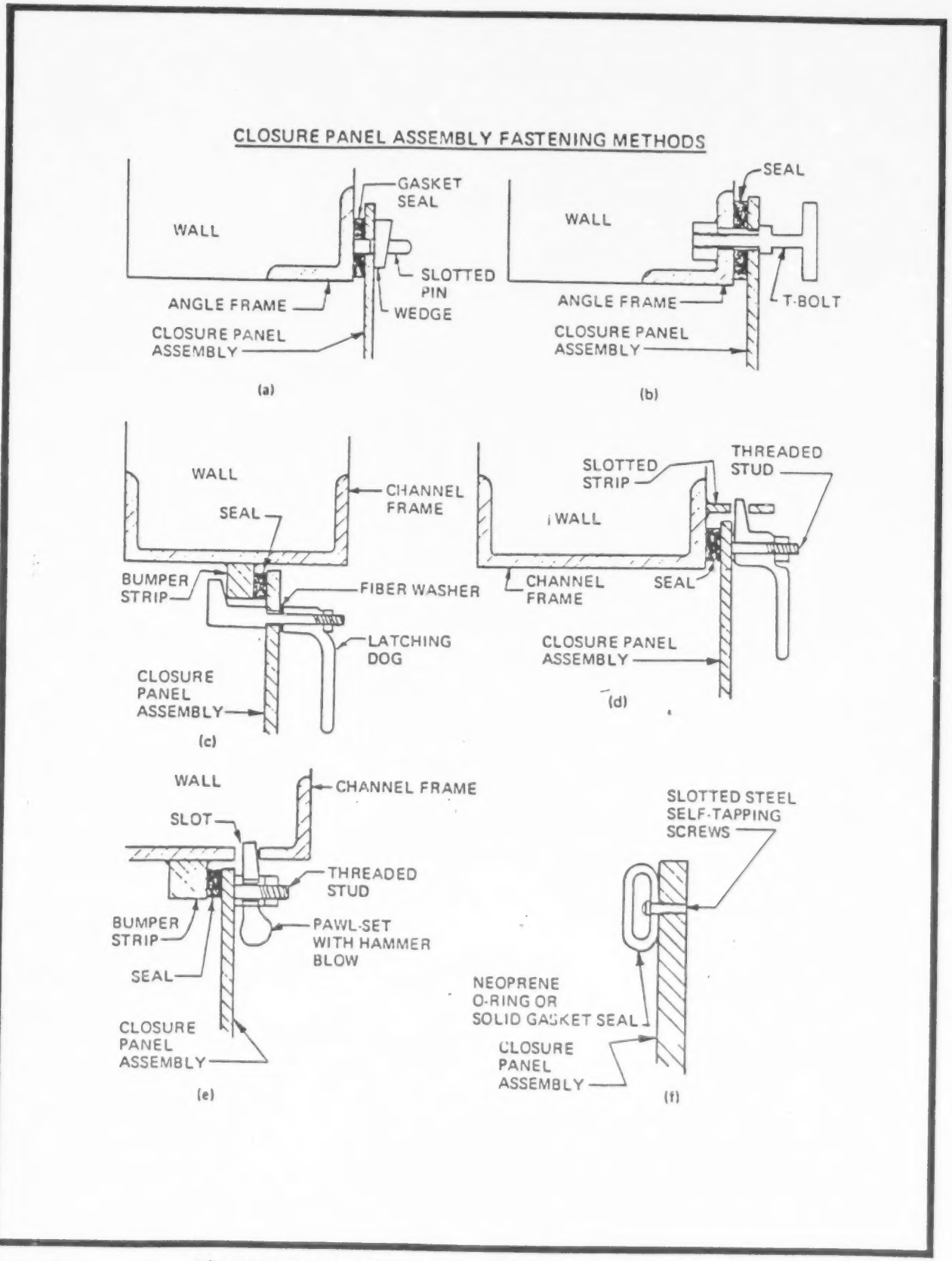


Figure 35 FASTENING DETAILS FOR WINDOW FLOOD SHIELDS (reference 9)

- Family members must determine and be aware of the warning time required to install closure devices.
- Drills must be conducted to make sure that closure units and fittings are in working order.
- Inspections must be conducted to assure that closures and sealants are present for all openings and have not been lost or stored away.
- Sewer and drain lines must be equipped with backflow devices.

Openings below the base flood elevation in existing buildings can often be eliminated, with alternative entry points provided at higher levels. Windows below flood level can sometimes be replaced by glass bricks, which allow light but can withstand moderate amounts of water pressure.

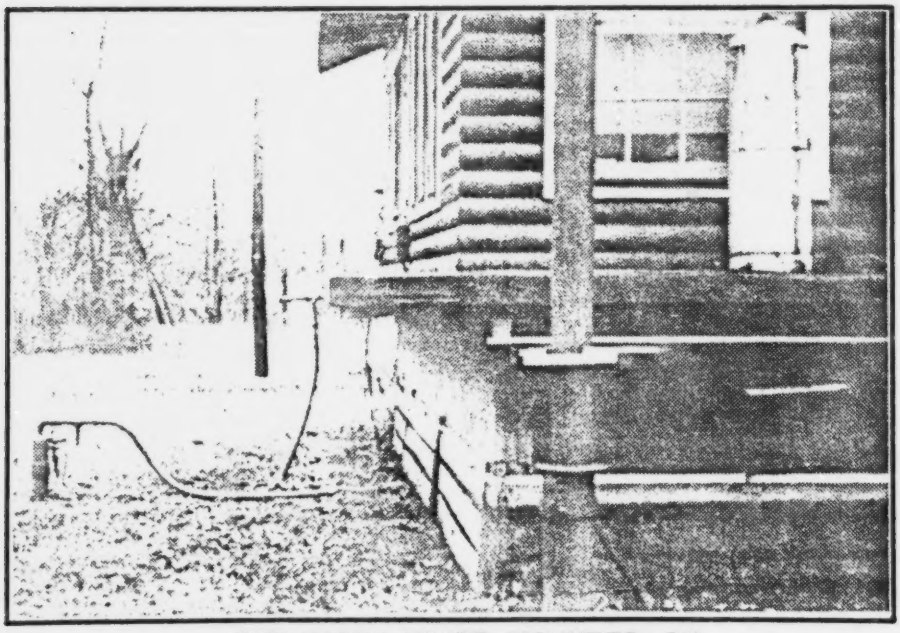
Because flood shields are custom designed and engineered for each application, it is difficult to make any general statements regarding prices. They may vary greatly from one manufacturer to another. Appendix E describes a variety of commercially available watertight doors and barriers.

Again, the requirement for flood warnings and human intervention is necessary to make this system effective.

4.3.6 OTHER METHODS

The U.S. Corps of Engineers has developed a method of wrapping houses with plastic or rubber sheeting. Although this method takes time to implement, apparently it has been used successfully and offers an inexpensive alternative for the property owner, particularly for houses with slab on-grade foundations. It is most commonly applied following a flood warning and is regarded as a flood contingency measure.

Another technique that is rarely seen in this area is to build the structure on pontoons or a barge-type foundation such that the structure floats during the flood. In this case, all land-based supporting facilities, utilities, etc., have flexible line connections. Refer to Appendix F for details.



ONE-STORY HOUSE MOUNTED ON
BARGE-LIKE FLOTATION SYSTEM

Figure 36 (reference 14)

4.4 WET FLOODPROOFING (Figure 37)

In this method, the house basement is made of materials which will sustain minimum or no damage when flooded. The primary advantage to this method is that hydrostatic loading is neutralized thus avoiding over-stressing of the walls and foundation. Contents located in floodable areas should be those which can be easily moved or minimally damaged. Contents that could become hazardous or create a pollution problem during a flood are not to be stored in floodable areas. Any amount of wet floodproofing can reduce structural damages; however, with this method the homeowner is still faced with after flood clean up, repairs, and other problems not associated with dry floodproofing.

Although it is an approved method for NHA financing, it is clearly a last resort and recommended solely for use when all of the dry floodproofing options could only be implemented with extreme difficulty or at prohibitive cost. It is not an option where the contents are more valuable than the structure.

Specific design requirements for wet floodproofing as mandated by CMHC are as follows:

A. Footings and Foundations

1. Footings and foundation walls shall be cast-in-place concrete.
2. Footing, foundation walls and floor slabs-on-ground shall be designed to resist all loads and influences that may be expected including hydrostatic pressure, and shall satisfy the requirements of Part 4 of the National Building Code of Canada 1985.
3. The designer shall be a professional engineer or architect skilled in such design and licenced to practice in accordance with the appropriate provincial or territorial legislation.

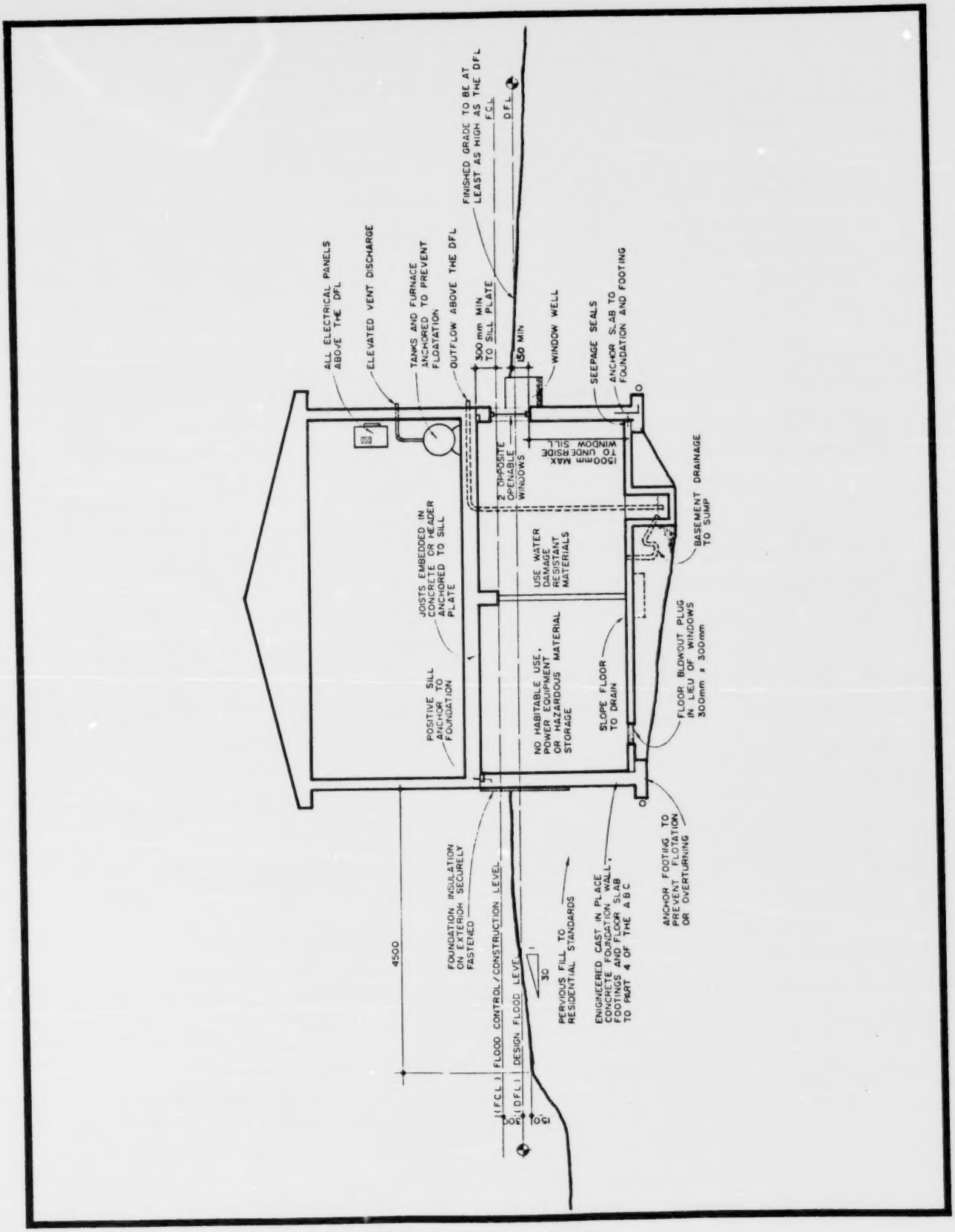

ALL ELECTRICAL PANELS ABOVE THE DFL
ELEVATED VENT DISCHARGE
TANKS AND FURNACE ANCHORED TO PREVENT FLOATATION
OUTFLOW ABOVE THE DFL
300 mm MIN TO SILL PLATE
150 MIN
FINISHED GRADE TO BE AT LEAST AS HIGH AS THE DFL
FCL
DFL
WINDOW WELL
SEEPAGE SEALS
ANCHOR SLAB TO FOUNDATION AND FOOTING
2 OPPOSITE OPENABLE WINDOWS
1500mm MAX TO UNDERSIDE WINDOW SILL
BASEMENT DRAINAGE TO SUMP
USE WATER DAMAGE RESISTANT MATERIALS
JOISTS EMBEDDED IN CONCRETE OR HEADER ANCHORED TO SILL PLATE
POSITIVE SILL ANCHOR TO FOUNDATION
NO HABITABLE USE, POWER EQUIPMENT OR HAZARDOUS MATERIAL STORAGE
SLOPE FLOOR TO DRAIN
FLOOR BLOWOUT PLUG IN LIEU OF WINDOWS 300mm x 300mm
FOUNDATION INSULATION ON EXTERIOR SECURELY FASTENED
4500
FLOOD CONTROL/CONSTRUCTION LEVEL
DESIGN FLOOD LEVEL
(FCL)
(DFL)
1
30
PERVIOUS FILL TO RESIDENTIAL STANDARDS
ENGINEERED CAST IN PLACE CONCRETE FOUNDATION WALL, FOOTINGS AND FLOOR SLAB TO PART 4 OF THE ABC
ANCHOR FOOTING TO PREVENT FLOTATION OR OVERTURNING

Figure 37

WET FLOODPROOFING

4. The clear height from the top of the basement concrete slab-on-ground to the underside of the first storey floor system including the beam shall be not less than 1930 mm.
5. Basement or cellar walls shall be provided with at least two openable windows located on opposite sides of the building. The top of the window sills shall not be less than 150 mm below grade to allow flood water into the basement to counteract the hydrostatic pressure.
6. The interior surfaces of basement or cellar walls and floors shall not have any finishing materials covering the concrete.
7. Basements shall not contain habitable space nor be used for storage of immovable materials or hazardous materials that are buoyant, flammable, explosive or toxic.
8. Foundation insulation shall be applied to the exterior and be fastened to prevent detachment during flooding.

B. Backfill

1. Backfill material shall be placed in accordance with Subsection 12.C of Residential Standards 1985.
2. Backfill material shall be graded at least up to the design flood level at the exterior of the foundation wall.
3. Backfill material shall be graded away from the foundation at a slope not exceeding 1-in-30 for a minimum distance of 4.5 metres. From this point the slope may be increased to 1-in-4 slope until the original grade level is reached.

C. Floor Construction

1. The area enclosed by the foundation walls shall be covered by a concrete slab in accordance with Article 16.F.1 of Residential Standards 1985.

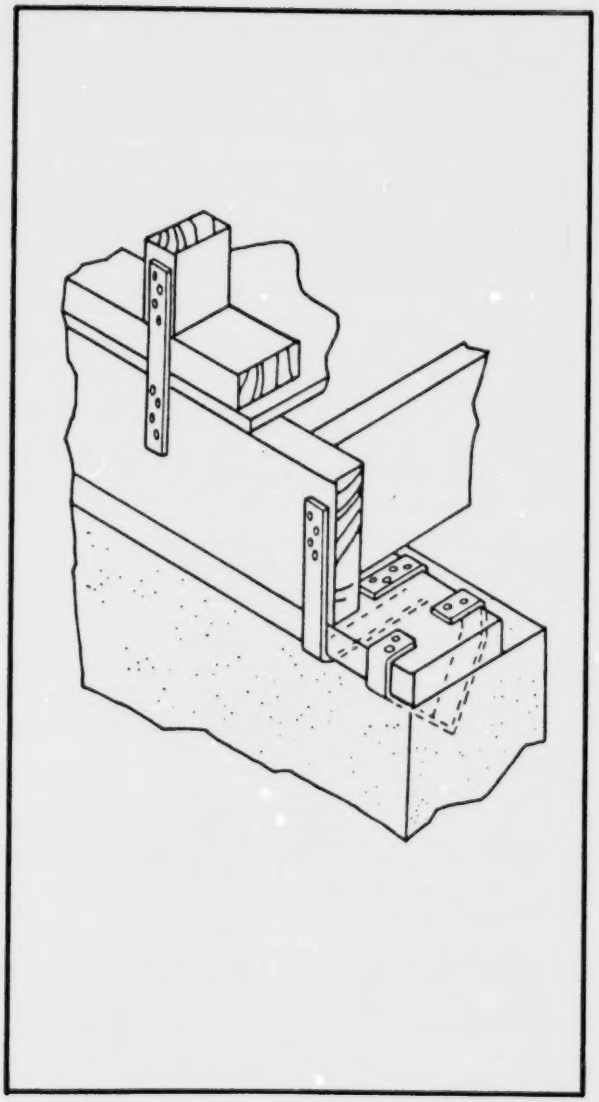
2. The top of a structural slab-on-ground supporting habitable portions of a building shall be minimum 300 mm above the design flood level.
3. Load-bearing floor slabs-on-ground shall be designed as required in Article A (2) and (3).
4. The underside of floor joists and sill plates supporting habitable portions of a building shall be minimum 300 mm above the design flood level.
5. The underside of wood beams supporting floors shall be minimum 300 mm above the design flood level.
6. Columns supporting floor loads shall be steel columns as required in Subsection 17.C of Residential Standards 1980.
7. Load-bearing walls constructed below the design flood level shall be cast-in-place concrete.

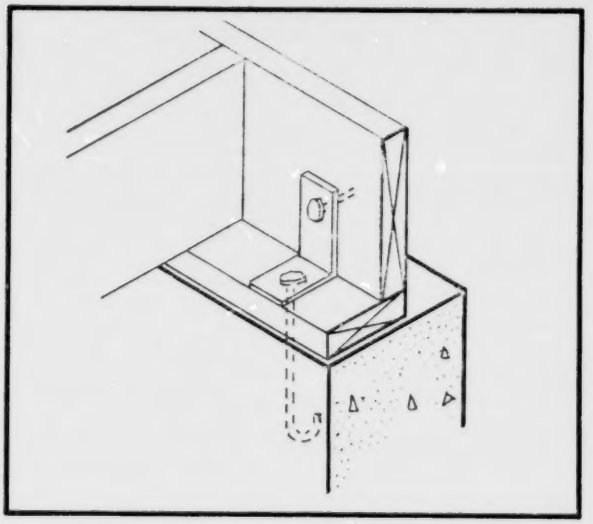
D. Anchorage (Figure 38)

1. Wood and steel frame buildings shall be anchored to the foundation to prevent the unit from floating off the foundation should the design flood level be exceeded.
2. Exterior walls built on floor slabs-on-ground shall be anchored as required in Article 23.F.2 of Residential Standards 1985.
3. First floor joists shall either have the ends embedded in the concrete foundation or the header joist mechanically fastened to the sill plate anchor bolts, or any system providing equivalent protection.

E. Basement or Cellar Drainage System

1. A covered sump pit with an automatic submersible pump shall be provided in all basements or cellars.
2. The outflow pipe shall discharge above the design flood level.





(reference 6)

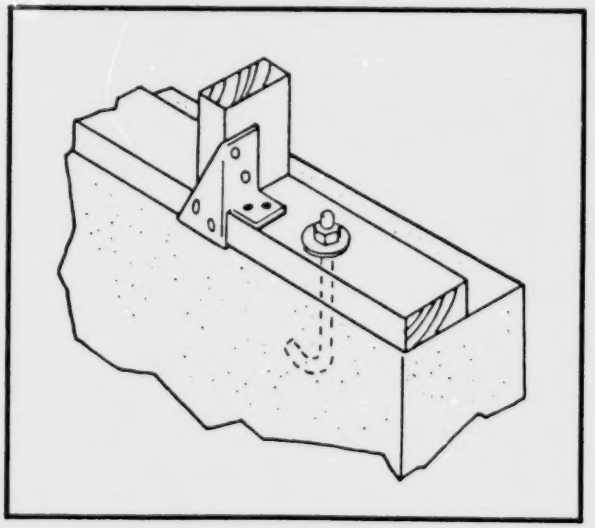


Figure 38 (reference 24) (reference 24)

SILL ANCHORAGES

3. A separate, electrical circuit shall be provided for the sump pump with the operating switch located above the design flood level.
4. Granular material under the basement or cellar slabs shall be graded so that the entire area is drained towards the sump pit.
5. Basements or cellars shall have a floor drain connected to the sump pit.
6. Basement or cellar slabs shall have a positive slope to the floor drain.
7. Floor drains or sump pumps shall not discharge to municipal sanitary sewage systems, but may discharge to municipal storm sewage systems when a backwater valve is installed.

F. Measures for Continued Occupancy

1. Casings for vented drilled wells shall extend to a point at least 150 mm above the design flood level or be capped.
2. Waste connections for plumbing fixtures shall not be made below the design flood level except as permitted in Subsection E.
3. Central heating units, such as oil, gas or electric forced air furnaces including all ductwork and service water heaters, shall not be installed below the design flood level.
4. Electrical service panels shall not be located below the design flood level. Electrical circuits servicing areas below the design flood level shall be on separate circuits and be capable of disconnection.

Some of the items noted above do not involve any additional cost over conventional non-flood proof construction whereas others do add some cost. McLaren's study indicated that a $550 premium during construction could reduce damage from water inundation by up to 80%.

Tables 12 and 13 (pages 120, 121) summarize the additional costs associated with wet floodproofing measures for new and retrofit construction. Providing for wet floodproofing in the prototypical 100 m^2 study house would increase costs by 6%. Wet floodproofing a similar existing house would increase costs by 17%.

Naturally in any comparison to "dry" floodproofing methods, additional cleanup costs must be allowed for. These costs would normally be higher for this technique than any others.

4.5 BUILDING SERVICES

4.5.1 GENERAL

Flood proofing techniques are applied not only to the main building structure itself but to the building services or urban support systems as well. The flood proofing of services should be integrated with the flood-proofing technique used for the structure.

Flood proofing of services, as with structural alternatives, is always more difficult to implement in existing buildings than it is at a proposed new facility where flood-proofed services can be incorporated from the planning stage.

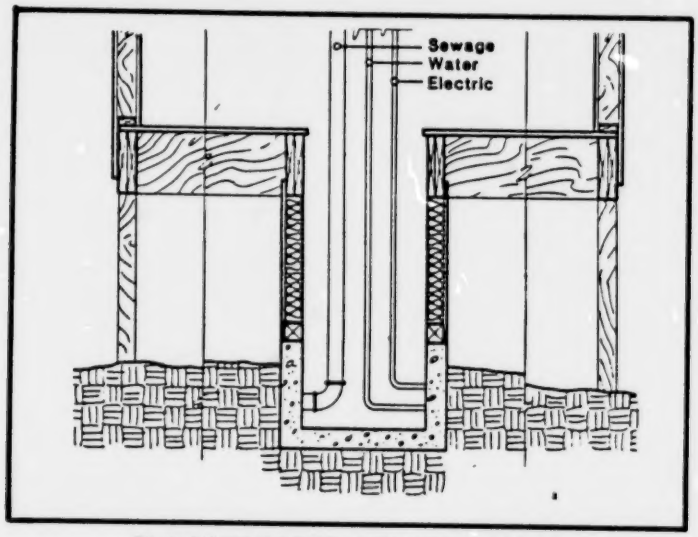
Structures in flood-prone areas are commonly served by combinations of electricity, water, sanitary sewer, gas and telephone. Typical installations for these utilities expose them to potential damage from flooding and storm action. In the case of an elevated first floor, the connection from an underground utility line to the floor above further exposes the line to possible damage and/or contamination by flooding and storm action. Underground services are also susceptible to damage when erosion of the protective soil cover leaves them exposed during flooding.

Damage to utility lines can lead to contamination of drinking water, discharge of effluent from sewer lines, gas explosions, and fires and/ or shock from damaged electrical systems.

The most vulnerable section of any underground utility line is the portion between the ground and the connection to the elevated first floor. A minimum amount of protection can be obtained by locating these utility risers on the sides of interior elevated foundation elements opposite the direction of flood water. This can minimize damage from high velocity water or floating debris.

A more secure method is to place all utility lines coming from underground within a protective, floodproofed shaft under the elevated first floor (Figure 39).

The continued operation of services during flooding is a definite advantage, especially during floods of long duration.



FLOODPROOFED UTILITY SHAFT

Figure 39 (reference 4)

4.5.2 HEATING

All mechanical equipment (furnaces, hot water heaters, air-conditioners, water softeners) should be elevated above expected flood waters or located in a water-tight enclosure. An attic location, if available, would provide maximum protection to the equipment. System design should attempt to keep all duct work and vents above the FCL. If this is not possible, then heating and/or cooling systems ductwork should be provided with emergency openings at their lowest elevations and a minimum slope on horizontal duct runs in order to allow the system to drain in case it becomes submerged.

When fixed heating and air conditioning equipment cannot be installed above the FCL, dikes around them can be used to hold back floodwater and also help protect them when intentional flooding is performed to protect parts of the structure. Diking would be a permanent measure that is functional at all times. Large, multi-family buildings could afford to provide a watertight vault for the mechanical equipment.

Fuel storage tanks are best located above the FCL. Alternatively as shown in Figure 40 they must be buried in the ground or securely anchored above grade and equipped with a float operated auto shut-off valve which is activated by rising floodwaters. In addition, a manually operated shut-off valve for the fuel supply which can be controlled from a point above the FCL should be installed. This is in case of line fracture and fuel spillage. Fuel lines must be attached to furnaces by flexible or swing type couplings. Access points into the house must be sealed. Interior fuel tanks must be vented to exterior above first floor level eaves.

Septic tanks should also be securely anchored as noted above and floodproofed to ensure that flooding does not cause the tank to rise out of the ground if the tank is partially empty. A water-proof cap is required as well as to ensure against discharge of effluent.

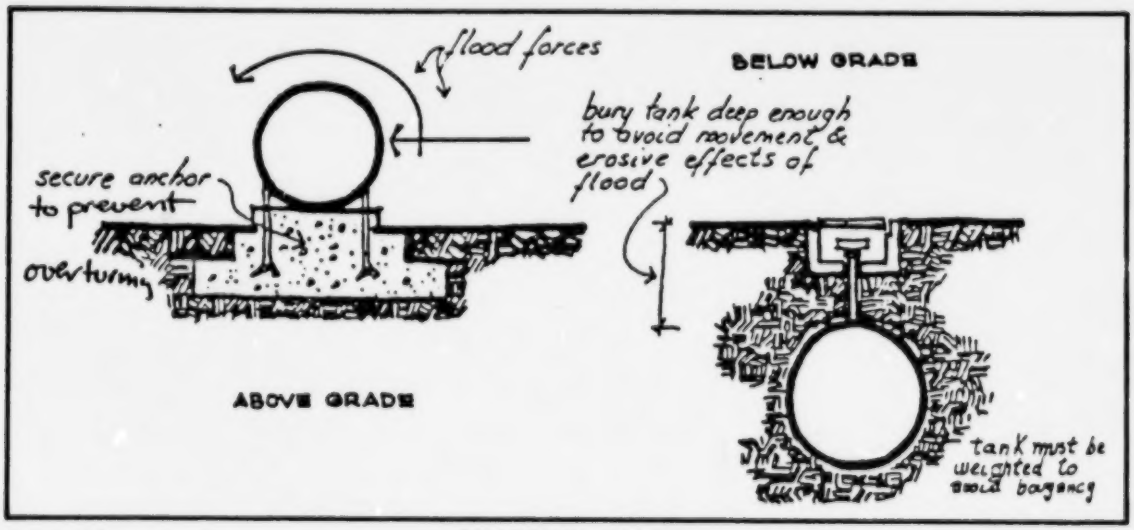

flood forces
BELOW GRADE
bury tank deep enough to avoid movement & erosive effects of flood
secure anchor to prevent overturning
ABOVE GRADE
tank must be weighted to avoid buoyancy

Figure 40 STORAGE TANKS (reference 27)

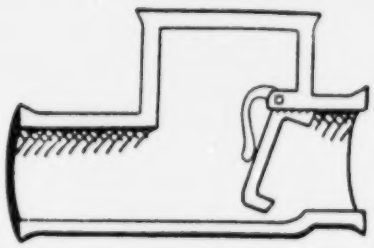
4.5.3 PLUMBING

Sewers and storm drains are the services most often affected during flooding; floodwaters flow into the outlets, increase pressure on the lines and frequently backflow into the structure. Sewer systems can be kept in operation through the use of shut off valves to prevent backup and the installation of pumps. The same pumps can also remove seepage from the building if outlets are provided which extend above known flood stages. Check valves, vacuum breakers or air gaps should be installed to prevent back siphoning.

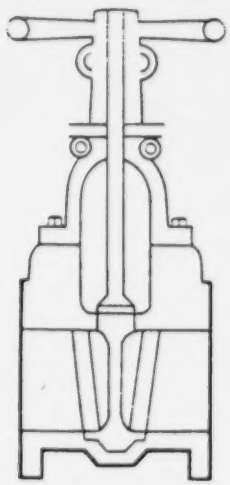
Plumbing fixtures shall be kept above the FCL or those below the FCL should be equipped with a backwater valve which stops reverse flow (Figure 41). This may be accomplished either by locating a valve on the main line, or using separate valves on all fixtures below the FCL.

Two principal types of backflow valves are used - the check valve, sometimes called a backwater valve and the gate valve.

A check valve will permit sewage to flow outward but will not allow backflow. Unfortunately, most check valves require frequent cleaning and maintenance to remain effective. This maintenance is

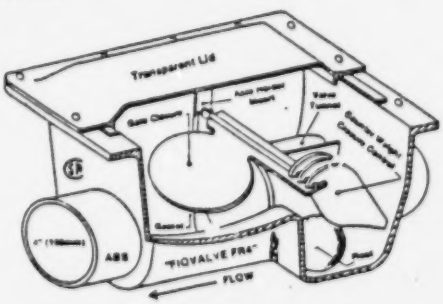


Check Valve



Gate Valve

Fiovalve



Dual Backflow Valve

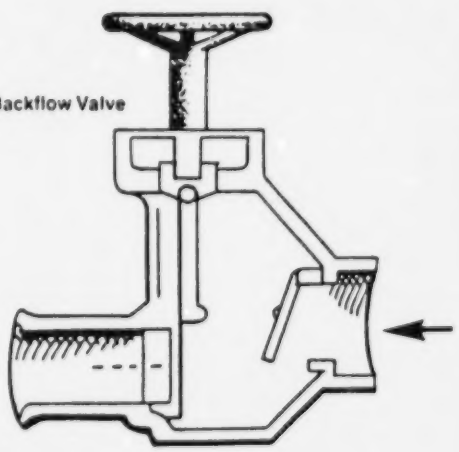


Figure 41 **BACKWATER VALVES** (reference 24)

beyond the ability of the average home owner. Consequently, the reliability of some check valves for residential use is open to question. A new check valve has been developed to overcome the problem. This checkvalve, called Fiovalve, F.R. 4, is a patented backwater valve which operates in the open position (see Figure 41). This feature allows its installation in the main waste line.

A gate valve is a manually operated valve which shuts off backflow and simultaneously shuts down the entire house sewer system. It does not require the frequent cleaning and maintenance of a check valve.

A third type of valve combines the check valve with a manually operated gate valve. This provides automatic check valve protection combined with the positive operation of the manual gate valve.

An alternative to the use of backwater valves is to eliminate all gravity flow drains below the FCL - including floor drains, drain tile, appliances and plumbing fixtures; these may be directed to a basement sump pump which lifts drainage above the FCL on a permanent basis. This method requires a reliable electrical power source which will not be disrupted during flooding or a backup power source which can be activated during flooding.

Another more complex alternative is a vacuum sewage system developed for low-lying areas which cannot be served economically by gravity flow.

Figure 42 summarizes additional plumbing considerations for floodproofing.

If the sanitary system is required to operate during flooding a sealed holding tank should be provided. The use of individual sewage disposal systems such as seepage pits is generally not adviseable; their use will depend on local or provincial Department or Ministry of Health requirements.

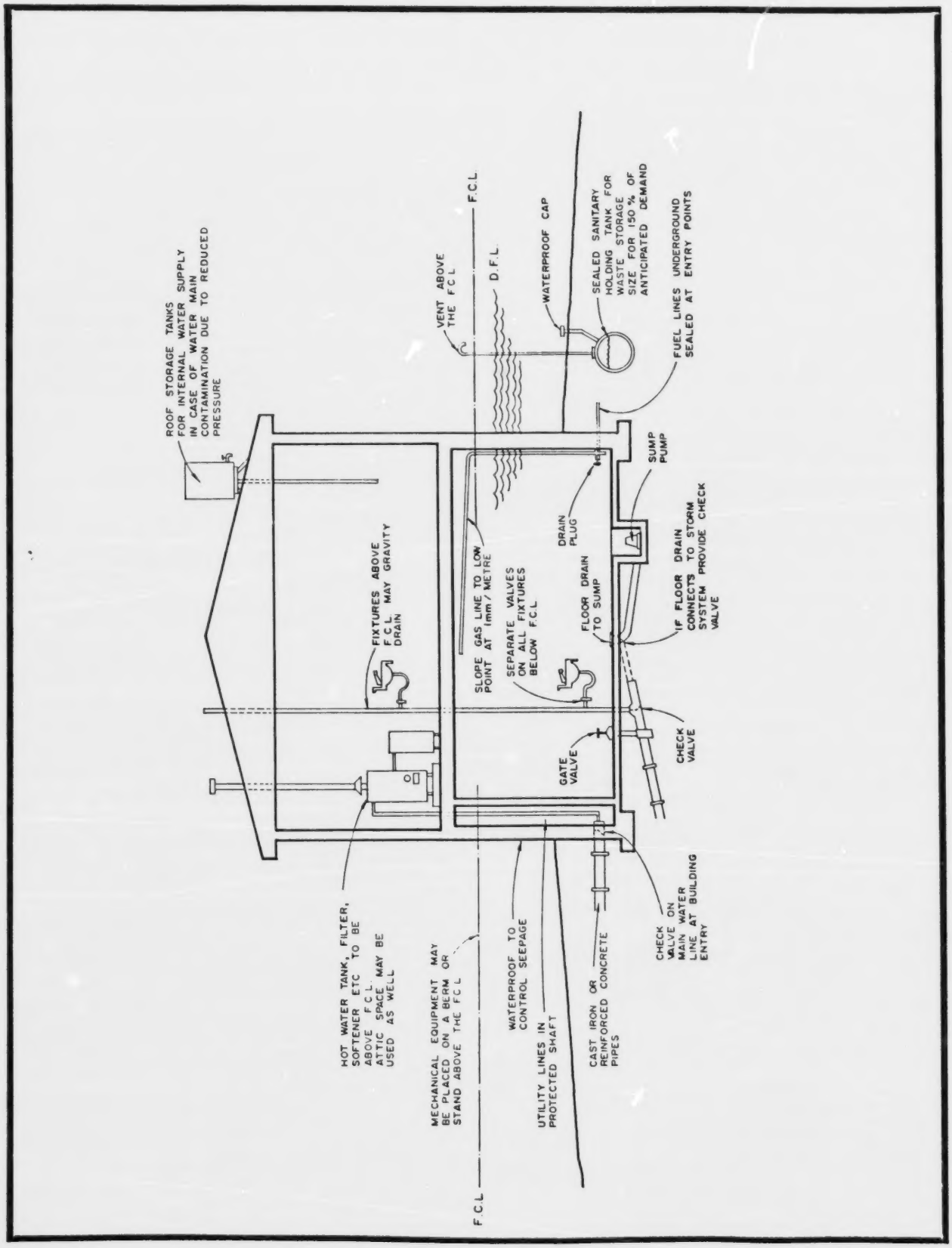

ROOF STORAGE TANKS FOR INTERNAL WATER SUPPLY IN CASE OF WATER MAIN CONTAMINATION DUE TO REDUCED PRESSURE
VENT ABOVE THE F.C.L
F.C.L
D.F.L
WATERPROOF CAP
SEALED SANITARY HOLDING TANK FOR WASTE STORAGE SIZE FOR 150 % OF ANTICIPATED DEMAND
FUEL LINES UNDERGROUND SEALED AT ENTRY POINTS
SUMP PUMP
DRAIN PLUG
FIXTURES ABOVE F.C.L MAY GRAVITY DRAIN
SLOPE GAS LINE TO LOW POINT AT 1mm / METRE
SEPARATE VALVES ON ALL FIXTURES BELOW F.C.L
FLOOR DRAIN TO SUMP
IF FLOOR DRAIN CONNECTS TO STORM SYSTEM PROVIDE CHECK VALVE
GATE VALVE
CHECK VALVE
HOT WATER TANK, FILTER, SOFTENER ETC TO BE ABOVE F.C.L ATTIC SPACE MAY BE USED AS WELL
MECHANICAL EQUIPMENT MAY BE PLACED ON A BERM OR STAND ABOVE THE F.C.L
WATERPROOF TO CONTROL SEEPAGE
UTILITY LINES IN PROTECTED SHAFT
CAST IRON OR REINFORCED CONCRETE PIPES
CHECK VALVE ON MAIN WATER LINE AT BUILDING ENTRY
F.C.L

Figure 42

PLUMBING SERVICES

4.5.4 ELECTRICAL (Figure 43)

All utility lines should be above Flood Control Level (FCL) or below grade, waterproofed, below erosion level and secured to prevent uplift.

If electrical and telephone lines are supplied from overhead service lines, they should be connected through the utility company's meter system above the expected reach of flood waters. However, this requirement is often in conflict with the power company's policy regarding the reading of meters and their location. If the meter is below the FCL, the connection should be made within a waterproof enclosure. All main distribution and control panels or other major electrical equipment should also be located above expected flood waters. Branch circuit wiring to receptacles and switches should be fed from the main floor ceiling downward to minimize wiring on the flood susceptible floors. Additional design considerations are listed below:

1) Waterproof all fittings below FCL.
2) Place telephone and transformers above FCL.
3) Install auxiliary generator and emergency lighting.
4) Feed all receptacles and switches below FCL from above FCL by separate circuit.
5) Provide separate circuit for sump pump. The pump may be activated by float warning device.
6) Use waterproofing wiring; limit circuit to 120 volts.
7) Provide electrical equipment below DFL which can be easily disconnected and portable or, if not removeable, must be submersion rated for 72 hours.

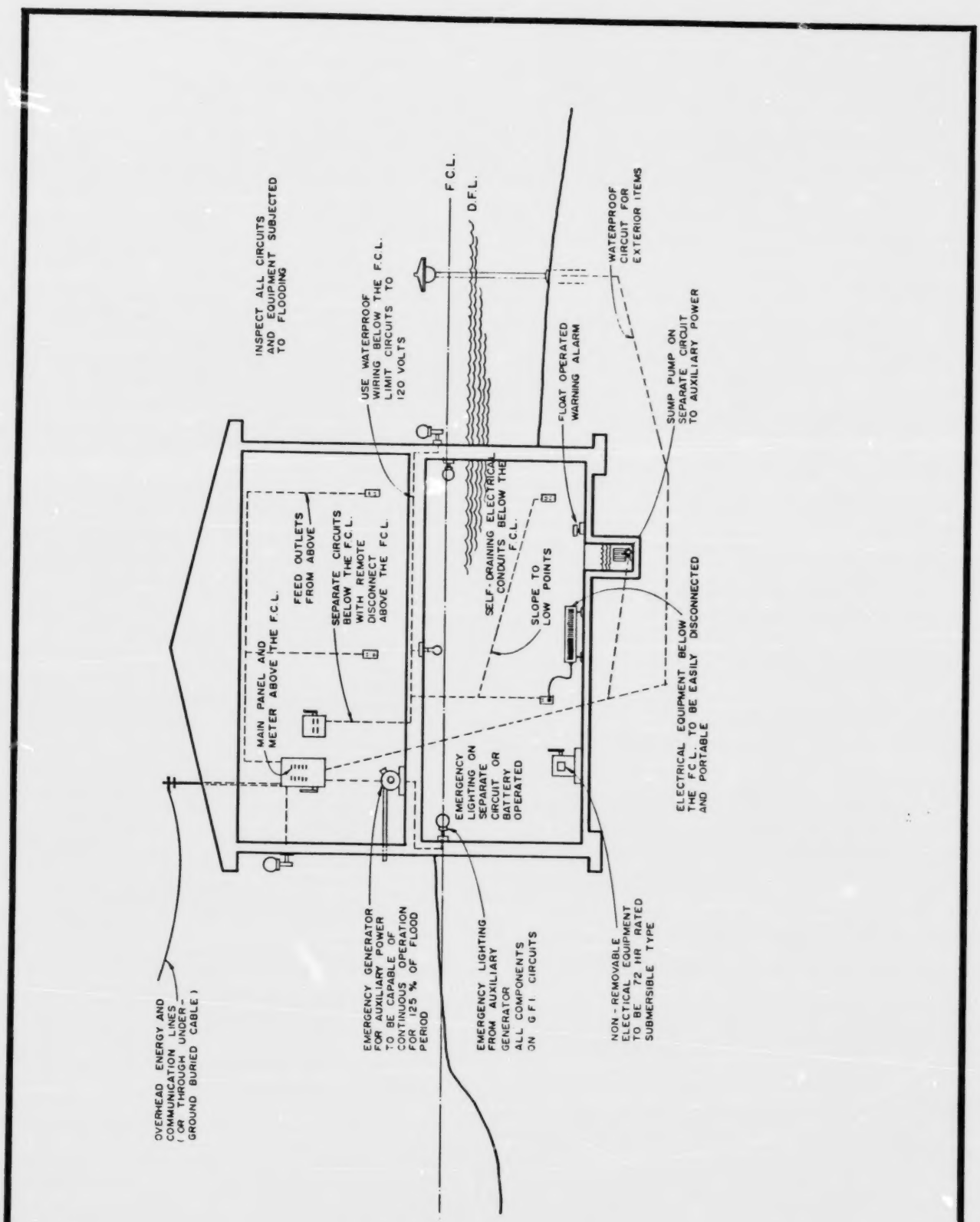

INSPECT ALL CIRCUITS AND EQUIPMENT SUBJECTED TO FLOODING
USE WATERPROOF WIRING BELOW THE F.C.L. LIMIT CIRCUITS TO 120 VOLTS
F.C.L.
D.F.L.
WATERPROOF CIRCUIT FOR EXTERIOR ITEMS
FLOAT OPERATED WARNING ALARM
SUMP PUMP ON SEPARATE CIRCUIT TO AUXILIARY POWER
MAIN PANEL AND METER ABOVE THE F.C.L.
FEED OUTLETS FROM ABOVE
SEPARATE CIRCUITS BELOW THE F.C.L. WITH REMOTE DISCONNECT ABOVE THE F.C.L.
SELF-DRAINING ELECTRICAL CONDUITS BELOW THE F.C.L.
SLOPE TO LOW POINTS
EMERGENCY LIGHTING ON SEPARATE CIRCUIT OR BATTERY OPERATED
ELECTRICAL EQUIPMENT BELOW THE F.C.L. TO BE EASILY DISCONNECTED AND PORTABLE
OVERHEAD ENERGY AND COMMUNICATION LINES (OR THROUGH UNDER-GROUND BURIED CABLE)
EMERGENCY GENERATOR FOR AUXILIARY POWER TO BE CAPABLE OF CONTINUOUS OPERATION FOR 125 % OF FLOOD PERIOD
EMERGENCY LIGHTING FROM AUXILIARY GENERATOR ALL COMPONENTS ON G.F.I. CIRCUITS
NON-REMOVABLE ELECTICAL EQUIPMENT TO BE 72 HR RATED SUBMERSIBLE TYPE

Figure 43

ELECTRICAL SERVICES

4.6 URBAN SERVICES & UTILITIES

Although not within the scope of this study, it is worth mentioning some important considerations for the infrastructure within a flood plain.

1) Elevate road surface above DFL. If built on fill this can be used as a dike. However, care must be taken not to obstruct the flood flow (Figure 44). Roads should be minimized to reduce the amount of surface paving. Site layout should locate roads to approach buildings from the direction away from the floodplain so that access routes will be less likely to be blocked by the flow of flood waters and debris. This approach will protect natural features in the floodplain and will minimize obstruction of the floodway. To reduce potential erosion, siltation, and runoff problems, roads should not disrupt drainage patterns, and road crossings should be perpendicular to streams, with adequate bridge openings and culverts to permit the unimpeded flow of water. If roads are to be raised, the slope of embankments should be minimized and open faces stabilized with ground cover or terracing.

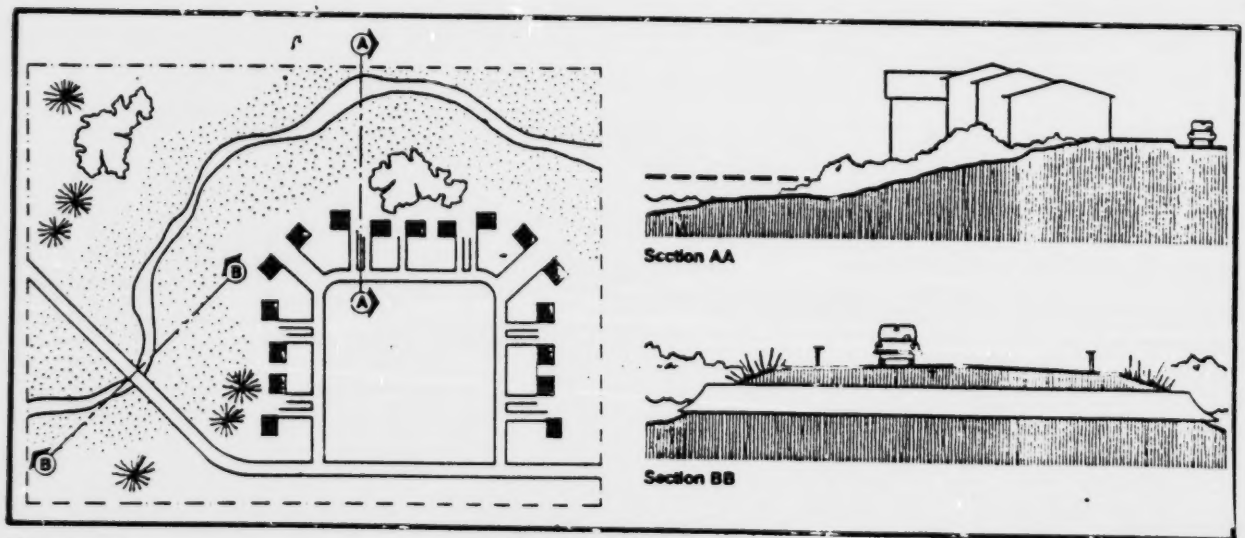


Figure 44 ROAD GRADING (reference 1)

2) Overhead hydro lines must be elevated or placed on well anchored concrete supports. However, this does not protect them from high winds or freezing rain. Use of buried waterproof cable is preferred.
3) Correct bedding and anchorage is required to prevent uplift of buried pipelines and cables.
4) The capacity of the storm sewer system can be impaired by sediment deposits within the systems; to avert this problem, drain inlets should be designed with sediment traps and filters (Figure 45).
5) Another alternative is a vacuum sewage system developed for low-lying areas which cannot be served economically by gravity flow.

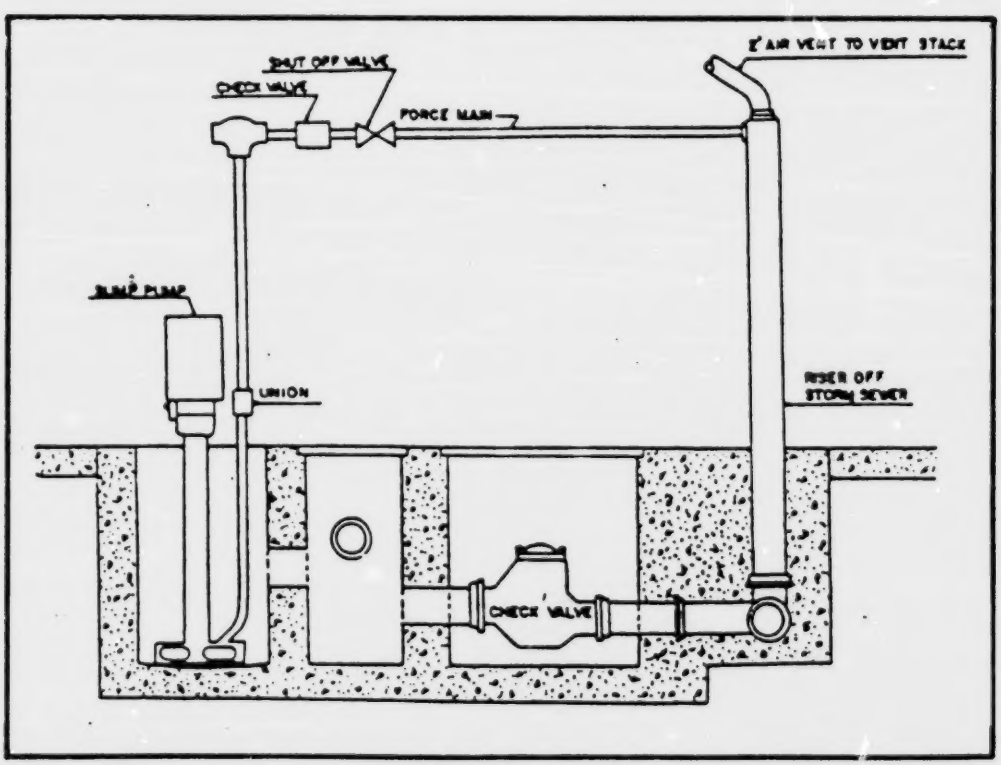


Figure 45 SEDIMENT TRAP (reference 26)

4.7 SITE DESIGN

The primary objective in siting buildings in respect of flooding considerations is to locate structures so that they will be safe (or can be made safe) from flood waters. Location and orientation of individual buildings must take into account the following considerations:

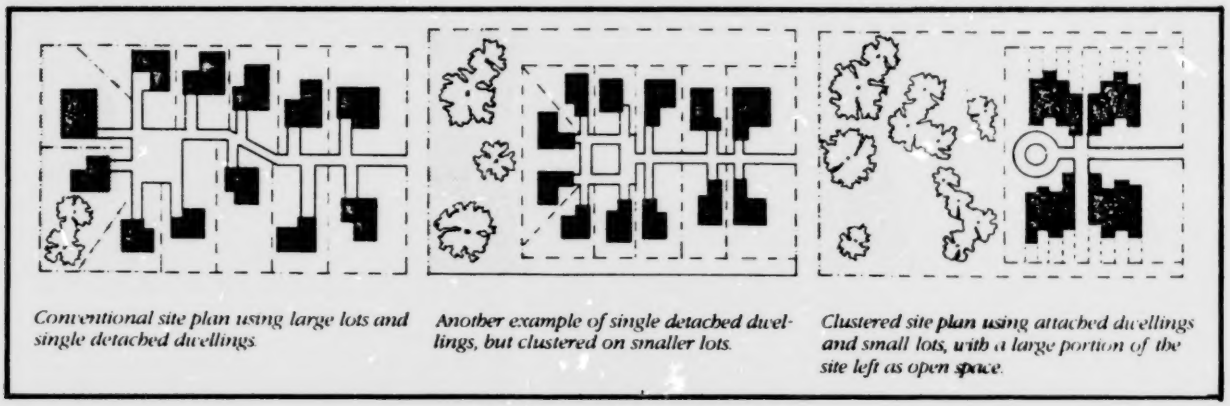
- Provide high ground access if possible
- Preserve natural drainage patterns and runoff features
- Observe floodway setback
- Design orientation of foundation and walls to minimize obstruction of flood flows
- In subdivisions or housing clusters locate streets and services to maintain access during flooding
- Observe good grading and drainage practices by providing for vegetation, sod or riprap on steeper slopes and channels (max. slope without special treatment is 8%)

When designing multiple building sites the above considerations hold true as well as providing the opportunity to perhaps restructure topography to divert runoff or stabilize slopes.

Cut and fill techniques can be used to create berms, floodwalls and lagoons, and the resulting level changes can delineate recreation, circulation and parking zones. It may also be possible to deepen adjacent waterflow channels for more floodwater capacity and at the same time obtain useable fill which can be shaped to minimize erosion and turbulence.

Cluster development should be considered where possible in new subdivisions to allow higher density development which makes it more economical to elevate foundations by berming etc. In addition, clustering buildings leaves more space for low-intensity use such as recreation and reduces the length of roadways (Figure 46). A reduction in impervious surface area such as street

paving would allow faster absorption of any floodwaters. Another alternative might be to encourage use of porous paving materials such as turfstone for low use roads and parking areas. Cluster development would mean less extensive street and utility systems with fewer, better protected, access routes. Some examples of this type of development are shown at the end of this chapter.



Conventional site plan using large lots and single detached dwellings.

Another example of single detached dwellings, but clustered on smaller lots.

Clustered site plan using attached dwellings and small lots, with a large portion of the site left as open space.

Figure 46 **CLUSTER DEVELOPMENT** (reference 1)

Looking at the overall site (Figure 47), it is important that the shape of the fill should be streamlined to minimize erosion due to turbulence. When there are two or more closely spaced buildings on individual mounds, an increase in velocity will result as the floodwaters are funnelled between the two mounds, greatly increasing erosion potential at this point. The channel must be shaped to provide gentle curves, gradual slopes and reduce obstructions such as large trees, rocks, fences, etc. Paving stones or well established sod are appropriate surfaces to minimize erosion.

Individual mounds should be oriented to the floodwater flow to minimize funnelling effect and to create pockets of slow moving water where possible. Placing buildings on common mounds reduces the number of problems locations and is possible in new subdivisions designs. The diagrams are not intended to imply that the building is in a floodway but is a graphic exaggeration of some flood effects experienced even in some flood fringe areas.

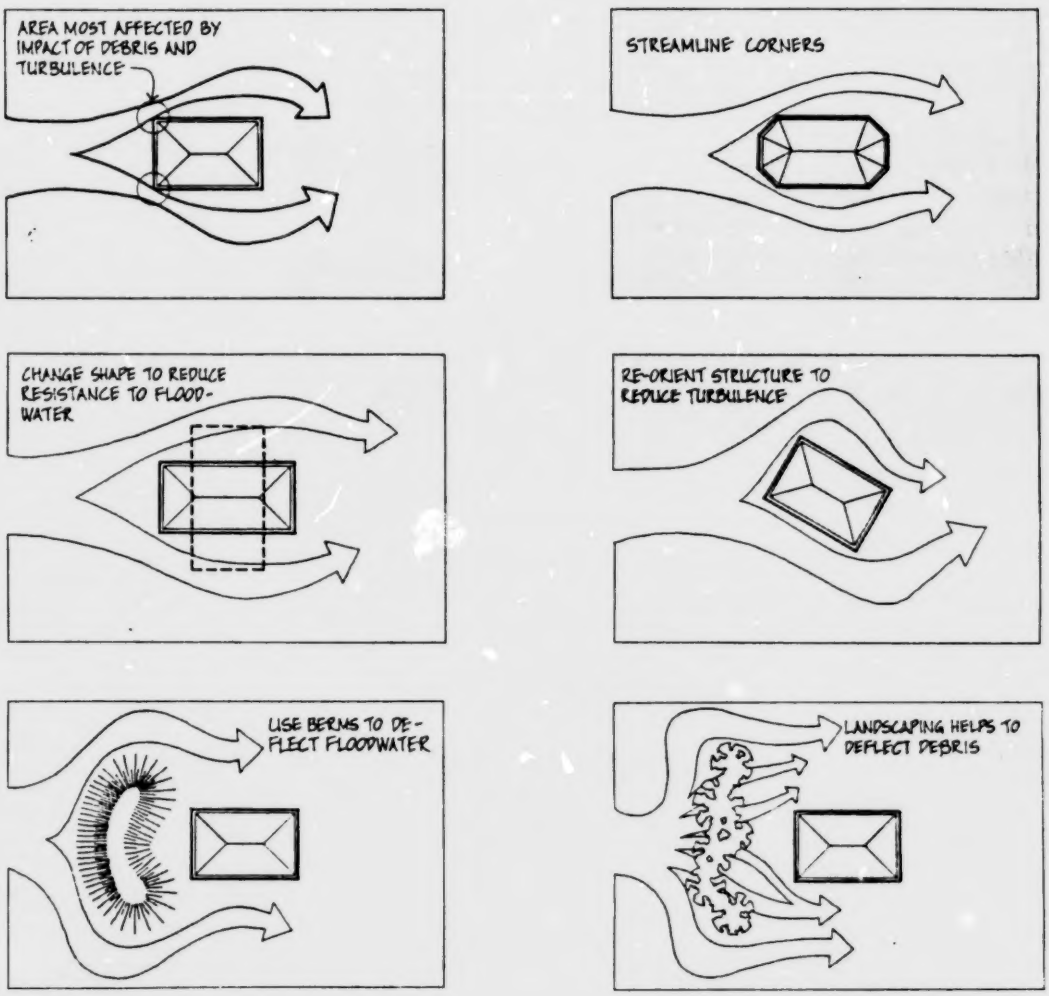

AREA MOST AFFECTED BY IMPACT OF DEBRIS AND TURBULENCE
STREAMLINE CORNERS
CHANGE SHAPE TO REDUCE RESISTANCE TO FLOOD-WATER
RE-ORIENT STRUCTURE TO REDUCE TURBULENCE
USE BERMS TO DE-FLECT FLOODWATER
LANDSCAPING HELPS TO DEFLECT DEBRIS

Figure 47 SITE DESIGN TO REDUCE FLOOD HAZARDS (reference 4)

5.0 COST BENEFIT ANALYSIS

There have been a number of theoretical cost benefit analyses done in the United States to determine the value of floodproofing vs. not floodproofing. However, there have been very few case study comparisons of specific floodproofing alternatives, especially as they relate to residential construction. The only Canadian documentation is contained in McLaren's 1978 study which reviewed alternative measures as applied to both new and existing structures. The conclusions reached at that time were as follows:

1) Variability in type of structure and site conditions can result in a wide premium range of 2-50% for dry floodproofing.

2) Floodproofing existing structures is more expensive than for new construction which can economically incorporate floodproofing features during construction. This premium averages 20% of the value of the building.

3) The relative cost (% of total cost) usually decreases with the size of the building (eg. the per unit cost of floodproofing a cluster group of homes is less than for individual units on a per sq.ft. basis).

4) Floodproofing by elevating new homes and small commercial developments on fill or columns is generally the least expensive approach. Large structures and many existing buildings can be most economically floodproofed by means of closures and seals or floodwalls and levees.

5) In general, the cost to floodproof a large new structure varies from 2-4% of the building cost and is about 10% for new single detached dwellings.

This study evaluated a prototypical design for both a new house, and retrofit of an existing residence in relation to the various floodproofing alternatives outlined in previous chapters. The average premiums for incorporating floodproofing measures into residences in the Alberta market were estimated and are summarized in Table 2.

These estimates were based on costs developed in the 1986 Alberta House Cost Comparison Study (prepared for Alberta Municipal Affairs) and on other assumptions explained in the notes following Table 2.

The analysis generally supports the conclusions reached in the McLaren study. Premiums for floodproofing new structures ranged from 5-10% of the base cost while premiums for floodproofing existing structures ranged from 17-47%.

TABLE 2: COMPARATIVE COST OF FLOODPROOFING ALTERNATIVES (1987)

ALTERNATIVE	BASE COST OF NEW NON-FLOODPROOFED BUILDING AND SITE DEVELOPMENT [1]	ADDITIONAL COST TO FLOODPROOF NEW BUILDING	PREMIUM	TOTAL COST OF NEW FLOODRPOOFED BUILDING	ADDITIONAL COST TO FLOODPROOF EXISTING BUILDING	PREMIUM
A. SLAB ON RAISED FILL	$38,800.00 [2]	$1,934.00 (Table 3)	5%	$40,734.00	$18,408.00 (Table 4)	47%
B. EXTENDED FOUNDATION - SUMP SYSTEM	$41,250.00 [3]	$2,414,00 (Table 5)	6%	$43,664.00	$12,195.00 (Table 7)	30%
C. EXTENDED FOUNDATION - BARGE SYSTEM	$41,250.00 [3]	$3,996.00 (Table 6)	10%	$45,246.00	$15,170.00 (Table 8)	37%
D. ELEVATION ON PILES	$37,457.00 [4]	$2,321.00 (Table 9)	6%	$39,778.00	$ 7,017.00 (Table 10)	19%
E. FLOODWALL	$41,250.00 [3]	$14,938.00 (Table 11)	36%	$56,188.00	$14,938.00 (Table 11)	36%
F. "WET" FLOODPROOFING	$41,250.00 [3]	$ 2,555.00 (Table 12)	6%	$43,805.00	7,210.00 (Table 13)	17%

REFER TO FOLLOWING PAGE FOR EXPLANATORY NOTES.

NOTES TO TABLE 2

1. Comparative base building costs have been derived from the cost of the prototype used in the 1986 Alberta House Cost Comparison Study, which is $38,797. The prototype, which is described in Appendix G, reflects an extended foundation system with basement which is fairly typical to Alberta.

2. Calculations for the building costs of slab on raised fill were based on the above model without basement and designed to meet Alberta Building Standards.

Base Building Cost	$ 38,797.00
Site Development based on a 543 m^3 sized lot (45 feet x 130 feet) (see Note 5)	1,842.00
Total Comparative Cost	40,639.00
Estimated 1987 Construction Cost Adjustment (1.5%)	611.00
Total	$ 41,250.00
Deduction for elimination of	
a) main floor framing	- $ 5,700.00
b) basement windows	- 350.00
Add cost of interior fill (compacted)	3,600.00
Total	$ 38,800.00

3. Building costs are based on Edmonton region 1986 price.

Base Building Cost	$ 38,797.00
Site Development based on a 543 m^3 sized lot (45 feet x 130 feet) (see Note 5)	1,842.00
Total Comparative Cost	$ 40,639.00
Estimated 1987 Construction Cost Adjustment (1.5%)	611.00
Total	$ 41,250.00

4. The prototype structure on wood piles was designed without a basement but costs were included for the floodproofed utility shaft and also for weather protection to the underside of the main floor assembly.

NOTES TO TABLE 2 (cont'd)

Base Building Cost	$ 38,797.00
Deduction for elimination of	
a) excavation, backfill and proofing, footings, foundation wall, floor slab	- 7,490.00
b) basement windows	- 350.00
Add cost of	
a) utility shaft	689.00
b) pile foundation complete with bracing and lintels	3,711.00
c) weather seal and insulation to underside of floor assembly	2,100.00
Total	$37,457.00

5. Cost Breakdown for Site Development Cost

Item	Unit Cost	Quantity	$
1. Rough Grade (included in Alberta Housing Study)	N/A	443 m^2	N/A
2. Topsoil, Graded	$11.59/$m^3$	44 m^3	510.00
3. Crushed Gravel (drive)	3.90/m^2	40 m^2	156.00
4. Sidewalks (pads)	7.50/m	20 m	150.00
5. Grassed Areas	2.88/m^2	391 m^2	926.00
6. Mechanical Service Connections	Not Included		N/A
7. Electrical Service Connections	Not Included		N/A
Total			$1842.00

Costs outlined above do not include for:

a) land and site clearance
b) site servicing
c) design fees and expenses
d) legal fees and expenses
e) marketing and real estate financing
f) appliances
g) general contractor's overhead and profit.

TABLE 3: COST BREAKDOWN: NEW STRUCTURE - SLAB ON RAISED FILL

DESCRIPTION	QUANTITY	UNIT	MATERIAL		LABOR		TOTAL COST	
			UNIT	TOTAL ($)	UNIT	TOTAL ($)	UNIT	TOTAL ($)
1. Credit for Shallow Excavation Requirement	100	cu.m.	(0.42)	(42)	(0.80)	(80)	(1.22)	(122)
2. Site Fill Requirement (High Standards of Control Required for Fill Placement)	538	cu.m.	1.25	673	0.92	495	2.17	1168
3. Rip Rap Erosion Cover on Slopes	350	sq.m.	1.20	420	0.65	228	1.85	648
4. Raised Gravel Drive	Item	l/s	10.00	10	40.00	40	50.00	50
5. Additional Sidewalk Steps (Terraced Site)	Item	l/s	0.00		100.00	100		100
6. Additional Anchorage of Framing to Foundations	20	Anchors	2.50	50	22.00	40	4.50	90
TOTALS				1111		823		1934

Note 1. This cost premium allows for raising the building height 1000 mm in accordance with items noted in Figure 16.

Note 2. Cost premium of $1934 is equivalent to $\$19.34/m^2$ of building gross floor area, or 5% ($1,934/$38,800).

TABLE 4: COST BREAKDOWN: EXISTING STRUCTURE - SLAB ON RAISED FILL

DESCRIPTION	QUANTITY	UNIT	MATERIAL		LABOR		TOTAL COST	
			UNIT	TOTAL ($)	UNIT	TOTAL ($)	UNIT	TOTAL ($)
1. Raise and Remove Building c/n Services (Subtrade Cost)	Item	l/s	2300	2300				2300
2. Provide Site Fill (reference new building)	538	cu.m.	1.25	673	0.92	495	2.17	1168
3. Building Fill	100	cu.m.	1.50	150	0.92	92	2.42	242
4. Extend Foundation (Cast-in Place Concrete)	41.7	sq.m.	62.11	2590	35.00	1460	97.11	4050
5. Replace Floor Slab	100	sq.m.	36.00	3600	22.00	2200	58.00	5800
6. Replace Floor Finishes	100	sq.m.	17.50	1750	4.50	450	22.00	2200
7. New Anchorage and Partition Repairs to Make Good Existing	40	Locations	35.00	1400	15.00	600	50.00	2000
8. Rip Rap Erosion Cover on Slopes	350	sq.m.	1.20	420	0.65	228	1.85	648
TOTALS				12883		5525		18408

Note 1. This cost premium allows for material quantities in raising the existing building height 1000 mm in accordance with items noted in Figure 16.

Note 2. Cost premium of $18408 is equivalent to $184.08/m^2 of building gross floor area or 47% ($18,408/$38,800).

Note 3. Costs for altering site improvements (ie. sidewalks, fencing, landscaping) to meet new levels have not been accounted for.

TABLE 5: COST BREAKDOWN: NEW STRUCTURE - EXTENDED FOUNDATION (SUMP SYSTEM)

DESCRIPTION	QUANTITY	UNIT	MATERIAL		LABOR		TOTAL COST	
			UNIT	TOTAL ($)	UNIT	TOTAL ($)	UNIT	TOTAL ($)
1. Backfill/Grade Adjustment	56	cu.m.	(1.25)	(70)	(0.83)	(47)	(2.08)	(117)
2. Additional Reinforcing at Slab/Wall Junction and Sill Locations	41.7	m	3.90	163	0.98	41	4.88	204
3. Additional Reinforcement to Concrete Slab	100	sq.m.	0.64	64	0.50	50	1.14	114
4. Sump and Sump Pump Assembly	1	Item	600	600	200	200	800	800
5. Dampproof Foundation Walls (Tar) Extra Cost Only	108	sq.m.	1.61	174	1.03	111	2.64	285
6. Ensure Adequate Lateral Support			N/C		N/C		N/C	
7. Treatment to Additional Exposed Foundation Wall	41.7	sq.m.	3.25	136	7.00	292	11.25	428
8. Elevating Exterior Steps	2	no.	75	150	30	60	105	210
9. Place Equipment Above Infiltrating Water	Item	l/s	350	350	140	140	490	490
TOTALS				1567		847		2414

Note 1. This cost premium allows for the building to be placed 1000 mm above the grade elevation that would normally be designed for (sump system) and illustrated in Figure 21.

Note 2. Cost premium of $2414 is equivalent to $24.14/m^2 of gross building floor area or 6% ($2,414/$41,250).

TABLE 6: COST BREAKDOWN: NEW STRUCTURE-EXTENDED FOUNDATION (BARGE SYSTEM)

DESCRIPTION	QUANTITY	UNIT	MATERIAL		LABOR		TOTAL COST	
			UNIT	TOTAL ($)	UNIT	TOTAL ($)	UNIT	TOTAL ($)
1. Backfill/Grade Adjustment	56	cu.m.	(1.25)	(70)	(0.83)	(47)	(2.08)	(117)
2. Additional Reinforcing/Waterstops at Slab/Wall Junction Includes Sill Fastenings	41.7	m	6.90	288	2.50	104	9.40	392
3. Additional Reinforcement to Concrete Slab	100	sq.m.	0.64	64	0.50	50	1.14	114
4. Waterproof Foundation (Bituthene 3000)	108	sq.m.	9.30	1004	5.23	565	14.53	1569
5. Ensure Adequate Lateral Support (Additional Bracing Required)	20.2	m	29.60	597	9.30	198	38.40	795
6. Extended Anchorage to Protect From Buyoncy	41.7	m	7.60	317	6.90	288	14.50	605
7. Treatment to Additional Exposed Foundation Wall	41.7	sq.m.	3.25	136	7.00	292	10.25	428
8. Elevating Exterior Steps	2	no.	75	150	30	60	105	210
TOTALS				2486		1510		3996

Note 1. This cost premium allows for the building to be placed 1000 mm above the grade elevation that would normally be designed for (barge system) as illustrated in Figure 21.

Note 2. Cost premium of $3996 is equivalent to $39.96/m^2 of gross building floor area or 10% ($3,996/$41,250).

TABLE 7: COST BREAKDOWN: EXISTING STRUCTURE - EXTENDED FOUNDATION (SUMP SYSTEM)

DESCRIPTION	QUANTITY	UNIT	MATERIAL		LABOR		TOTAL COST	
			UNIT	TOTAL ($)	UNIT	TOTAL ($)	UNIT	TOTAL ($)
1. Raise Building From Existing Grade (Subtrade)	1	Item	1500	1500				1500
2. Extend Foundation								
a) With Cast-in-Place Concrete	41.7	sq.m.	62.00	2585	35.00	1460	127.00	4045
b) Preparation and Tie-ins	41.4	m	4.92	205	21.80	910	26.72	1115
3. Mechanical Services								
a) Disconnect and Connect	Item		60	60	240	240	300	300
b) Sump & Pump Assembly	1	Item	600	600	200	200	800	800
c) Raise Above Infiltrating Water	Item		350	350	400	400	750	750
4. Electrical Services	Item		100	100	250	250	350	350
5. Dampproofing	149	sq.m.	4.05	603	3.00	447	7.05	1050
6. Excavate Building Perimeter	96	cu.m.			2.50	240	2.50	240
7. Backfill Building Perimeter	110	cu.m.	3.00	330	3.20	352	6.20	682
8. Architectural Treatment to New Exterior Wall	41.7	sq.m.	3.80	158	9.00	375	12.80	533
9. Lateral & Misc. Structural Support (Allowance)	Item		300	300	200	200	500	500
10. Sump Hole & Filter Preparation	1	Item	250	250	400	400	650	650
11. Elevating Existing Steps	2	no.	130	260	70	140	200	400
TOTALS				7301		5614		12195

Note 1. This cost premium includes for raising the building and extending the foundation 1000 mm above existing grade to meet requirements shown in Figure 21.

Note 2. Cost premium of $12195 is equivalent to $121.95/m^2 of gross building floor area or 30% ($12,195/$41,250).

TABLE 8: COST BREAKDOWN: EXISTING STRUCTURE - EXTENDED FOUNDATION (BARGE SYSTEM)

DESCRIPTION	QUANTITY	UNIT	MATERIAL		LABOR		TOTAL COST	
			UNIT	TOTAL ($)	UNIT	TOTAL ($)	UNIT	TOTAL ($)
1. Raise Building From Existing Grade	1	Item	1500	1500			1500	1500
2. Extend Foundation								
a) Cast-in-Place Concrete	41.7	sq.m.	62.00	2585	35.00	1460	127.00	4045
b) Preparation and Tie-ins	41.4	m	4.92	205	21.80	910	26.72	1115
3. Mechanical Service Connections	Item		60	60	240	240	300	300
4. Electrical Services	Item		50	50	200	200	250	250
5. Waterproof Foundation (Bituthene 3000)	149	sq.m.	9.30	1386	5.23	780	14.53	2166
6. Excavate Building Perimeter	96	cu.m.			2.50	240	2.50	240
7. Backfill Building Perimeter	110	cu.m.	3.00	330	3.20	352	6.20	682
8. Extended Anchorage (Buoyancy) & Related Slab Repairs	41.4	m	15.20	629	12.00	497	27.20	1126
9. Lateral & Misc. Structural Support (Allowance)	Item		700	700	500	500	1200	1200
10. Architectural Treatment to New Exterior Wall	41.7	sq.m.	3.80	158	9.00	375	12.80	533
11. Elevating Exterior Steps	2	no.	130	260	70	140	200	400
12. Additional Reinforcement to Concrete Slab	100	sq.m.	11.83	1183	4.30	430	16.13	1613
TOTALS				9046		6124		15170

Note 1. This cost premium includes for raising the building and extending the foundation 1000 mm above existing grade to meet requirements shown in Figure 21.

Note 2. Cost premium of $15170 is equivalent to $151.70/m^2 of gross building floor area or 37% ($15,170/$41,250).

Note 3. Premiums will vary according to structural suitability of the existing building.

TABLE 9: COST BREAKDOWN - ELEVATED NEW STRUCTURE ON PILES

DESCRIPTION	QUANTITY	UNIT	MATERIAL		LABOR		TOTAL COST	
			UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
1. Extend Piles by 1 Metre	12	no.	34.65	416	10.35	124	45.00	540
2. Cladding/Siding for Increased Height (Add $1500.00 to clad u/side of floor instead)	41.4	sq.m.	15.00	621	8.50	360	25.30	981
3. Mechical & Electrical Service Extension	1	m	55.00	55	275.00	275	330.00	330
4. Increase Service Shaft Length (reference Figure 37 on sheet 103)	1	m	180.00	180	80.00	80	260.00	260
5. Exterior Steps	2	no.	75.00	150	30.00	60	105.00	210
TOTALS				1422		899		2321

Note 1. This cost premium allows for extensions to the building height 1000 mm, based on a wood pile design. Reference items noted in Figure 30.

Note 2. Cost premium is equivalent to $\$23.21/m^2$ of gross building floor area or 6% ($2,321/$37,457).

Note 3. No allowance has been made for the loss of useable basement space.

TABLE 10: COST BREAKDOWN: EXISTING STRUCTURE ON NEW ELEVATED PILES

DESCRIPTION	QUANTITY	UNIT	MATERIAL		LABOR		TOTAL COST	
			UNIT	TOTAL ($)	UNIT	TOTAL ($)	UNIT	TOTAL ($)
1. Raise Building (Subtrade)	Item	l/s	1400	1400				1400
2. Extend Foundation with Concrete Piers	12	no.	80	960	40	480	120	1440
3. Prep. & Tie-In	41.4	m	4.92	205	21.80	910	26.72	1115
4. Mechanical Service Tie-In & Extension	Item		100	100	300	300	400	400
5. Electrical Service Tie-In and Extensions	Item		50	50	100	100	150	150
6. Cladding/Siding	47.6	sq.m.	15	714	8.50	405	23.50	1119
7. Increase Service Shaft Height	1	m	180	180	80	80	260	260
8. Clad/Project u/Side of Floor Assembly	100	sq.m.	5.33	533	1.60	160	6.93	693
9. Elevate Existing Exterior Steps	2	no.	120	240	100	200	220	440
TOTALS				4382		2635		7017

Note 1. This cost premium includes raising an existing building designed on pile foundation by 1000 mm. Reference Figure 30.

Note 2. Cost premium is equivalent to $70.17/m2 of gross building floor area or 19% ($7,017/$37,457).

TABLE 11: COST BREAKDOWN - FLOODWALL

DESCRIPTION	QUANTITY	UNIT	MATERIAL		LABOR		TOTAL COST	
			UNIT	TOTAL ($)	UNIT	TOTAL ($)	UNIT	TOTAL ($)
I Floodwall Anchorage (includes excavation, concrete, rebar, backfill & compaction)	100	m	26.92	2692	9.85	985	36.77	3677
II Filter Drain Ditch (includes excavation, top-soil removal, gravel fill, sump pump & electrical connection)	100	m	11.90	1190	5.46	546	17.36	1736
III Concrete Floodwall (includes concrete, formwork, reinforcement, expansion joints, finishing & making good)	100	m	57.45	5745	27.05	2705		8450
IV Flood Shields	2	m	150	300			150	300
V. Culvert with Backflow Valve	1	no.	180	180	20	20	200	200
VI. Impervious Cutoff (options for porous soil)	100	m	5.30	530	0.45	45		575
TOTALS				10637		4301		14938

Note 1. This cost involved for estimates to provide a 1 m high x 100 m long floodwall illustrated in Figure 31.

Note 2. The cost estimate of $14938 is calculated at $149.38/m of floodwall required.

Note 3. Prices are net (contractor mark-up not included).

TABLE 12: COST BREAKDOWN: WET FLOOD PROOFING - NEW BUILDING

DESCRIPTION	QUANTITY	UNIT	MATERIAL		LABOR		TOTAL COST	
			UNIT	TOTAL ($)	UNIT	TOTAL ($)	UNIT	TOTAL ($)
1. Additional Operable Window (optional blow out plug in lieu)	1	Item	110	110	30	30	140	140
2. Exterior Applied Foundation Insulation	50	sq.m.	0.90	45	0.40	20	1.30	65
3. Sump Pit and Sump c/w Electrical/Drainage Connections	Item	l/s	600	600	200	200	800	800
4. Positive Sill Anchorage	20	no.	2.50	50	2.00	40	4.50	90
5. Additional Tank & Furnace Anchorage	Item		10.00	10	20.00	20	30.00	30
6. Backwater Valve	1	no.	200	200	30.00	30	230	230
7. Modifications for Mechanical and Electrical Service to be Located Above Design Flood Level	Item	l/s	700	700	500	500	1200	1200
TOTALS				1715		840		2555

Note 1. This cost premium includes for wet floodproofing methods illustrated in Figure 37.

Note 2. Cost premium is equivalent to $\$25.55/m^2$ of gross building floor area or 6% ($2,555/$41,250).

Note 3. 5 m^2 of occupancy space on main floor will be required for mechanical/electrical service room.

TABLE 13: COST BREAKDOWN: WET FLOODPROOFING - EXISTING BUILDING

DESCRIPTION	QUANTITY	UNIT	MATERIAL		LABOR		TOTAL COST	
			UNIT	TOTAL ($)	UNIT	TOTAL ($)	UNIT	TOTAL ($)
1. Extra Operable Window (optional blow-out plug)	1	no.	150	150	70	70	220	220
2. Exterior Applied Foundation Insulation c/w Related Excavation & Backfill	50	sq.m.	2.80	140	12.00	600	14.80	740
3. Sump & Pump c/w Electrical/ Drainage Connections	1	no.	750	750	250	250	1000	1000
4. Sump Hole & Filter Preparation	Item	1	250	250	400	400	650	650
5. Backwater Valve	1	no.	350	350	250	250	600	600
6. Relocate Mechanical & Electrical Services Above Design Flood Levels	Item	l/s	2000	2000	1000	1000	3000	3000
7. Misc. Items (ie. preservative water treatment, positive sill anchorage, slope for slab drainage, seepage seals, etc.)	Item	l/s	500	500	500	500	1000	1000
TOTALS				4140		3070		7210

Note 1. This cost premium includes for wet floodproofing methods illustrated in Figure 37.

Note 2. Cost premium is equivalent to $\$72.10/m^2$ of gross building floor area or 17% ($7,210/$41,250).

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ANALYSIS OF A SMALL COMMERCIAL BUILDING
Federal Emergency Management Agency
Washington, D.C.
January 1978

30. Tennessee Valley Authority, Floodplain Management Branch
FLOODPLAIN MANAGEMENT: THE TVA EXPERIENCE
Tennessee Valley Authority
Knoxville, Tennessee
December 1983

31. U.S. Corps of Engineers
THE DEVELOPMENT OF NONSTRUCTURAL ALTERNATIVES - A POLICY DISCUSSION BY THE ST. PAUL DISTRICT
May 1979

32. U.S. Army Corps of Engineers
FLOOD PROOFING REGULATIONS
ENGINEERING BOOKLET 1165-2-314
Office of the Chief of Engineers U.S. Army
Washington, D.C.
June 1972

33. U.S. Army Corps of Engineers
South Western Division, Tulsa District
CASE STUDY: RELOCATION OF A LARGE, SLAB ON-GRADE HOUSE
Tulsa, Oklahoma
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34. U.S. Army Corps of Engineers
PROCEEDINGS OF A SEMINAR ON NON-STRUCTURAL FLOOD PLAIN MANAGEMENT MEASURES
The Hydrologic Engineering Center
and
Institute for Water Resources
July 1976

35. U.S. Water Resources Council
A UNIFIED NATIONAL PROGRAM FOR FLOOD PLAIN MANAGEMENT
Washington, D.C.
September 1979

APPENDIX A: CONTACT AGENCIES

1. ALBERTA ENVIRONMENT - PLANNING DIVISION
2. ENVIRONMENT CANADA - INLAND WATERS DIRECTORATE
3. CITY OF EDMONTON - RIVER VALLEY PLANNING GROUP
4. CITY OF CALGARY PLANNING DEPARTMENT
5. CANADA MORTGAGE AND HOUSING CORPORATION
6. CITY OF EDMONTON WATER & SANITATION
7. US. WATER RESOURCES COUNCIL
8. COLORADO WATER CONSERVATION BOARD
9. ONTARIO MINISTRY OF NATURAL RESOURCES
10. U.S. FEDERAL EMERGENCY MANAGEMENT AGENCY
11. U.S. ARMY CORPS OF ENGINEERS - WATER RESOURCES INSTITUTE
12. BRITISH COLUMBIA MINISTRY OF ENVIRONMENT

APPENDIX B

SUMMARY OF FLOODPLAIN STUDIES

INDEX NO.	RIVER	LOCATION	YEAR	AUTHOR	STATUS
1	Peace River	Fort Vermilion	1968	E. Yaremko	Current
2	Clearwater River	Butte	1972	G. Samide	Current
3	Highwood River	High River	1974 1983	NWHCL NWHCL	Outdated No Delineation
4	North Saskatchewan River	Edmonton	1974	S. Lowe	Outdated
5	Elbow River	Redwood Meadows	1975	P.F.R.A.	Current
6	Notikewin River	Manning	1976	M.E. Quazi	Current
7	Sawridge Creek	Slave Lake	1976	M.E. Quazi	Current
8	Pembina River	Sangudo	1976	H. Rickert	Current
9	Red Deer River Bearberry Creek	Sundre	1977	S. Lowe	Current
10	Athabasca River	Athabasca	1977	L. Garner	Current
11	Kneehills Creek	Carbon	1977	B. Nachukwu	Outdated
12	Lee Creek	Cardston	1978	D. Outhet	Outdated
13	Athabasca River	Whitecourt	1978	D. Outhet	Current
14	Crowsnest River	Coleman Blairmore & Frank	1978	G. Beckstead	Current
15	Sheep River	Black Diamond Turner Valley	1978	D. Andres	Extended
16	McLeod River	Cadomin	1978	S. Lowe	Map Only
17	Battle River	Ponoka	1979	H. Rickert	Current
18	Pincher Creek	Pincher Creek	1980	G. Beckstead	Current
19	Kettles Creek	Pincher Creek	1980	Stanley Associates	Current
20	Nose Creek	Airdrie	1980	Hydrocon	Current
21	Bow River	Banff	1980	G. Beckstead	Current
22	Waskasoo Creek	Penhold	1982	G. Fonstad	Current
23	East Prairie River	Metis Colony	1982	NWHCL	Current
24	Bow River Elbow River/Nose Creek	Calgary Calgary	1983 1983	S. Lowe F. Hicks	Updated Updated
25	Pipestone Creek	Millet	1983	EPEC Consultants	Current
26	Whitemud River	Dixonville	1983	T. Winhold	Current
27	Elbow River	Bragg Creek	1984	K. Dykema	Current
28	Vermilion River	Vegreville	1984	T. Winhold	Current
29	Athabasca River Clearwater River	Fort McMurray	1984	NWHCL	Map Only
30	Waskasoo Creek	Red Deer	1984	P. LaRocque	Current
31	Red Deer River	Drumheller	1984	B. Bigornia	Updated
32	Peace River	Peace River	1984	Biberhofer Consultants	No Delineation
33	Embarras River	Robb	1984	P. LaRocque	Map Only
34	West Castle River	Pincher Creek	1985	B. Bigornia	Current
35	Bow River	Cochrane	1985	T. Winhold	Current
36	Blackmud Creek	Leduc	1985	B. Bigornia	Current
37	Sturgeon River	St. Albert	1985	P. LaRocque	Updated
38	Sheep River	Okotoks	1985	S. Lowe	Updated
39	South Saskatchewan River	Medicine Hat	1986	T. Winhold	Updated
40	Oldman River	Lethbridge	1986	P. LaRocque	Extended/Updated
41	Oldman River	Fort MacLeod	1986	S. Lowe	Current
42	Red Deer River	Red Deer	1986	T. Winhold	Current

APPENDIX C: EARTH FILL REQUIREMENTS

Soil testing of a proposed fill area should be performed to establish bearing capacity of the foundation soil and requirement for the fill soil. Potential settlement should also be investigated with soil tests. The best preventive tool against excessive settlement is to ensure proper compaction when placing the fill material.

Soils with the best characteristics for use in a structure-supporting fill are well-graded sands and gravels, which may contain a small percentage of fine clay material. Undesirable soils include the highly plastic, swelling clays and also soils which are difficult to compact - cohesionless silts and very fine uniform sand. With proper methods, most inorganic soils will create an acceptable fill. Before suitable fill is put in place, existing vegetation and any unstable topsoil must be removed.

After a suitable fill material has been identified, placement should be done at or near the optimum moisture content for compaction. Using appropriate compaction equipment, such as pneumatic or sheepfoot rollers or vibrating compactors, the fill should be placed in layers no greater than 300 mm thick. Compaction to 95 percent of the Standard Proctor density in accordance with standard engineering practice will suffice for most residential building applications.

The Standard Proctor Test Method (ASTM D698-78, AASHTO T-180-74) is defined as follows: Twenty five blows of a 5.5 lb hammer falling 12 inches on each of three equal layers in a four inch diameter 1/30 ft^3 cylinder. The effort is 12,400 $ft\text{-}lb/ft^3$, which is comparable to light rollers or very thorough tamping in thin layers. If the soil contains many particles larger than a No. 4 sieve, a six-inch diameter cylinder of the same height is used and the blows increased to 55 per layer.

APPENDIX C (cont'd)

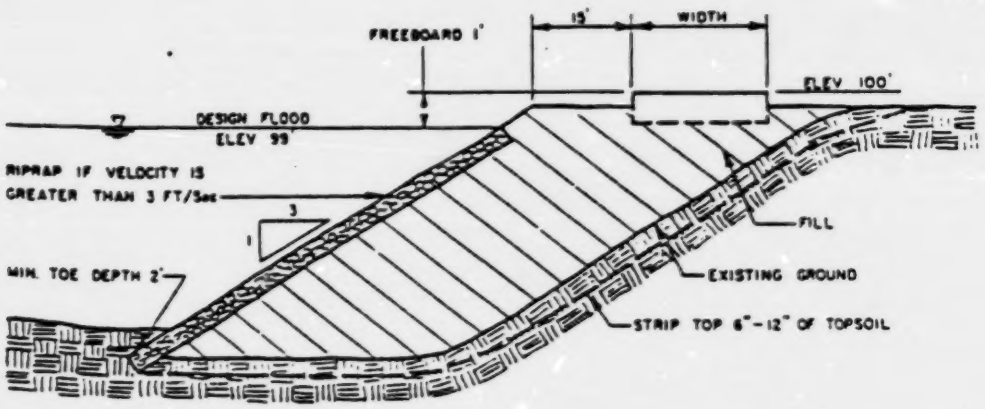
The drawing below shows the geometry for a typical raised-on-fill construction. Some very general recommendations are given here:

1. Local code requirements may vary, but the finished floor elevation should be a minimum one foot above the DFL.

2. Riprap should be placed on the slopes if the stream velocity will exceed three fps. General riprap requirements call for 12" to 24" mean diameter riprap with a unit weight from 150 to 165 pounds per cubic foot, placed in a layer at least 1.75 times the mean diameter.

3. The minimum horizontal distance that the fill should extend beyond the exterior of the structure should be 15 feet.

4. Slope stability calculations are best done by a professional engineer with the specific soil parameters. Recommended fill slopes for riprap lined embankments are 2.5:1 to 3:1. For vegetation lined embankments the recommended fill slope is a maximum of 4:1.



(reference 9)

If I already own a building in a flood-risk area, can I add to or improve it with NHA funds?

If you were authorized to build your house or project in an area that has since been designated a flood plain, you can still receive funding under the NHA without special requirements, but only within certain conditions. These conditions are that you make no significant alterations or extensions to the originally approved structure, or that any such alterations or extensions meet CMHC's floodproofing requirements.

Am I still eligible for RRAP funding if my building is in a flood-risk area?

You may still be eligible for funding under CMHC's Residential Rehabilitation Assistance Program (RRAP), if your house or housing project was built or was authorized to be built before the area was designated a flood plain. To be eligible for RRAP funding, you must meet the following requirements:

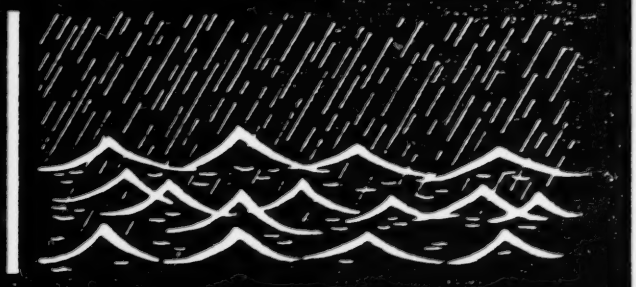
1. If the dwelling is located in the fringe area of a designated flood plain, any alterations or any "further undertakings" (described below) must conform to CMHC's floodproofing requirements.
2. If the dwelling is in a one-zone area (a floodway) or if it is in the floodway of a two-zone area, "further undertakings" are not allowed.

Further undertakings

1. Any new structure or addition to an existing structure within a designated flood-risk area will be considered a further undertaking and will not be eligible for funding under the NHA.
2. Where two zones are designated, structures or additions that are flood-proofed and are located in the flood fringe area — not the floodway — may be eligible for consideration under the NHA.
3. Work that could be classified as maintaining, repairing or upgrading existing structures, provided that such work does not increase the flood-vulnerable floor space of the property, will not be considered further undertakings. This includes:
   - insulating
   - upgrading services (wiring, plumbing)
   - putting on a new roof
   - installing a basement (if this does not lead to further flood damage)
   - repairing a structure partially damaged by fire, flood, tornado or other natural hazard.
4. Alterations that change the physical nature of a building or rehabilitation on a massive scale will be considered further undertakings. These include:
   - finishing a basement
   - any ground floor addition, including the enclosure of existing open porches or carports
   - gutting an old structure and redoing the inside (massive rehabilitation)
   - rebuilding, after fire, flood, tornado or damage by other natural hazard, a structure with a larger flood-vulnerable size than the original structure.

APPENDIX E

Flood Protection Products



WATERTIGHT DOORS & BARRIERS

MR/Manufacturer

INTRODUCTION

Presray...specialists in solving difficult sealing problems.

The Presray Corporation, a subsidiary of Pawling Rubber Corporation, specializes in designing and fabricating efficient, leaktight doors, barriers and seals. Presray has been designing and fabricating custom seals and closures for over twenty-five years. When you contact Presray you can be confident you're in reliable hands. Presray's custom designed products have greatly facilitated the job of those involved with designing and building perfectly sealed enclosures.

Contact us for recommendations on including Presray products in any type of new or existing construction including: masonry block, poured concrete and structural steel.

THE PNEUMA-SEAL PRINCIPLE

Most Doors and Flood Barriers can be positively sealed by using PNEUMA-SEAL®. The seal is inflated with air or other fluid by a pressure regulated supply system (which can also be furnished by Presray). When pressurized, the seal conforms to uneven surfaces and provides an efficient, reliable barrier to water. (Five domestic patents issued, others pending).

Where use of Pneuma-Seals is not practical or possible, Presray offers appropriate mechanical rubber gasketing in unlimited configurations.

PP/Product Presentation

PL FLOOD BARRIERS (PLFB)

U.S. Patent Nos. 3, 397, 490 & 3, 796, 010

A Presray PL Flood Barrier system consists of both a panel with Pneuma-Seal inflatable gaskets on the sides and across the bottom, and a conversion frame for installation in the opening to be sealed. The frame is permanently installed, whereas the panel and seal are installed, or positioned, at time of anticipated flood.

When the Pneuma-Seal gasket is inflated, the barrier effectively restrains flood waters, thereby "preventing losses" (hence the name PL).

PL Flood Barriers are applicable to both new and existing construction. The ideal structural or architectural requirement is that there be a slight setback into which the frame and panel can be placed.

The inconspicuous conversion frame can be installed against any surface such as brick, block, steel, etc. If no recess or setback exists in the door opening, a surface-mounted frame can be provided.

PL Flood Barriers are most effective in structures where the main flood problem occurs through entryways or other openings. Flooding in buildings with unsealed foundations will not be prevented, but can be minimized with PL Flood Barriers.

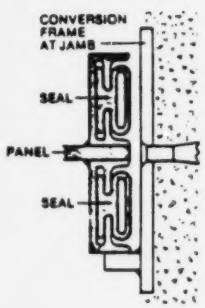
PLFB11 FLOOD BARRIERS For New or Existing Construction

Lift-out aluminum flood panel for manual installation—with inflatable seals and conversion frame for openings up to 4'0" wide.
Air supply system to pressurize seals supplied as an option where plant or facility air not available.

SPECIFICATIONS PRESRAY PLFB11

The flood panel shall be Presray type PLFB11. It shall be designed to resist a maximum _____(to be specified) head of water over its entire span with a minimum safety factor of 2:1 based on the yield strength of the material. The panel shall be constructed of 6061-T6 aluminum plate and extrusions to minimize weight. The panel is to be equipped with two Presray type 1 Pneuma-Seal inflatable gaskets held in place by extruded aluminum retainers.

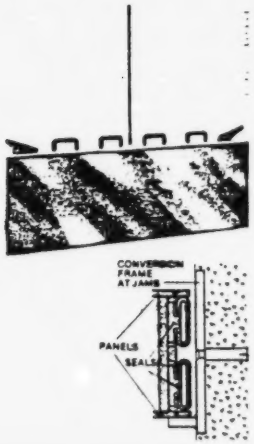
The mounting frame shall have radiused inside corners to insure maximum sealing and a threshold of 3/8" maximum thickness to provide a permanent sealing surface. The frame shall be provided with mounting holes on the side for expansion anchors and bolts, and the threshold shall have either concrete anchors welded to its underside or have counter-sunk holes for expansion anchors and flathead screws. Sealant/caulking should be applied, at installation, under the entire frame and along the edges to make the frame watertight. The frame shall be approximately 1/8" narrower than the masonry opening.



The panel is to be equipped with quick-acting manually operated bolts to lock the panel in position. Two handles shall be mounted on the top edge to facilitate manual positioning.
Each seal shall have a valve stem with a check valve similar to those used in automotive tires, and a 0 to 60 psi pressure gauge to measure seal inflation pressure.
After the panel is placed in position and the bolts engaged, the seals shall be inflated with a standard automotive tire valve, the normal inflation pressure to be 25 to 30 psi.

PLFB22 FLOOD BARRIERS For New or Existing Construction

Lift-out aluminum flood panel for manual installation—with inflatable seals and conversion frame for openings over 4'0" wide.
Air supply system to pressurize seals supplied as an option where plant or facility air not available.



SPECIFICATIONS PRESRAY PLF22

The flood panel shall be Presray type PLFB22. It shall be designed to resist a maximum _____(to be specified) head of water over its entire span with a minimum safety factor of 2:1 based on the yield strength of the material. The panel shall be constructed of 6061-T6 aluminum plate with two Presray type 1 Pneuma-Seal inflatable gaskets held in place by extruded aluminum retainers. The mounting frame shall have radiused inside corners to insure maximum sealing and a threshold of 3/8" maximum thickness to provide a permanent sealing surface. The frame shall be provided with mounting holes on the side for expansion anchors and bolts, and the threshold shall have either concrete anchors welded to its underside or have counter-sunk holes for expansion anchors and flathead screws. Sealant/caulking should be applied, at installation, under the entire frame and along the edges to make the frame watertight. The frame shall be approximately 1/8" narrower than the masonry opening.

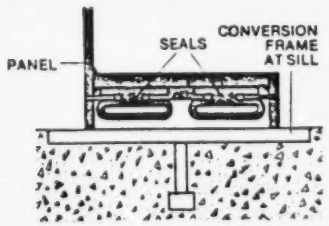
The panel is to equipped with quick-acting manually operated bolts to lock the panel in position. Four handles shall be mounted on the top edge, two to allow handling by a fork lift and two for manual positioning.

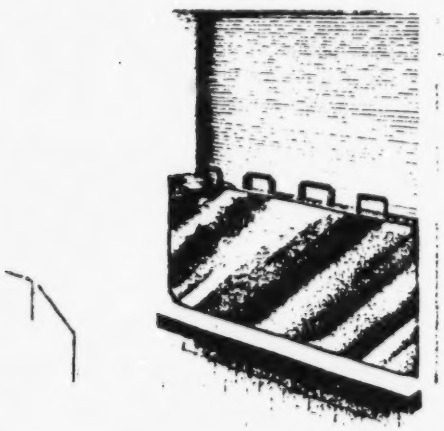
Each seal shall have a valve stem with a check valve similar to those used in automotive tires, and a 0 to 60 psi pressure gauge to measure seal inflation pressure.

After the panel is placed in position and the bolts engaged, the seals shall be inflated with a standard automotive tire inflate valve, the normal inflation pressure to be 25 to 30 psi.

PLFB33 FLOOD BARRIERS For New or Existing Construction

Lift-out steel flood panel (for installation by fork lift truck or equivalent capacity equipment) with inflatable seals and conversion frame for wide openings.
Air supply system to pressurize seals supplied as an option where plant or facility air not available.





SPECIFICATIONS PRESRAY PLFB33

The flood panel shall be Presray type PLFB33. It shall be designed to resist a maximum _____(to be specified) head of water over its entire span with a minimum safety factor of 2:1 based on the yield strength of the material. Panel and frame shall be constructed of steel plate stiffened as required with steel bars and shapes. The panel is to be equipped with two Presray type 1 Pneuma-Seal inflatable gaskets with Presray type B retention system.

The mounting frame shall have radiused inside corners to insure maximum sealing and a steel threshold of 3/8" maximum thickness to provide a permanent sealing surface. The frame shall be provided with mounting holes on the side for expansion anchors and bolts, and the threshold shall have either concrete anchors welded to its underside or have countersunk holes for expansion anchors and flathead screws. Sealant/caulking should be applied, at installation, under the entire frame and along the edges to make the frame watertight. The frame shall be approximately 1/8" narrower than the masonry opening.

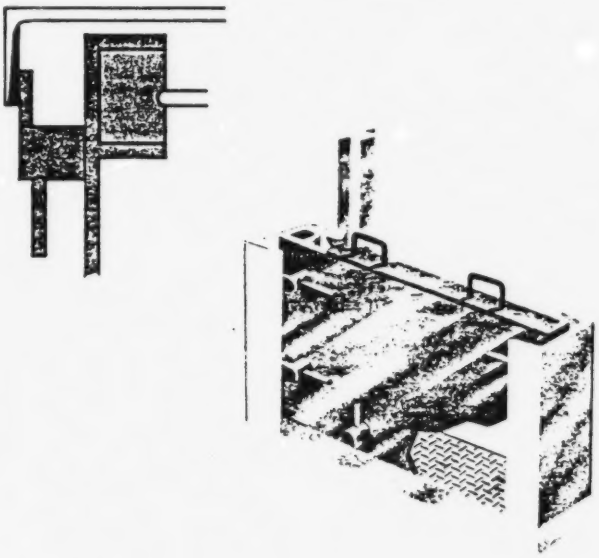
The panel is to be equipped with quick-acting manually operated bolts to lock the panel in position. Four handles shall be mounted on the top edge, two to allow handling by a fork lift and two for manual positioning.

Each seal shall have a valve stem with a check valve similar to those used in automotive tires, and a 0 to 60 psi pressure gauge to measure seal inflation pressure.

After the panel is placed in position and the bolts engaged the seals shall be inflated with a standard automotive tire inflate valve, the normal inflation pressure to be 25 to 30 psi.

PLFBCG11S FLOOD BARRIERS For New Construction

Lift-out heavy duty flood panel with compression gasketing and flush threshold conversion frame for openings of all sizes.



SPECIFICATION PRESRAY PLFB CG11S

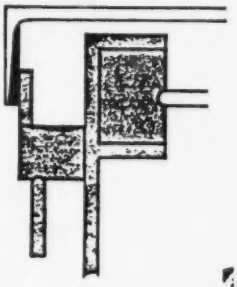
The flood barrier shall be Presray type PLFB CG11S. It shall be designed to resist a maximum ____(to be specified) head of water over its entire span with a minimum safety factor of 2:1 based on the yield strength of the material. The panel shall be constructed of A-36 steel or 6061-T6 aluminum plate. The panel shall include a 20 durometer neoprene (compound 3202) compression gasket. The gasket shall be installed in a retaining channel and shall contact a radiused coaming when the panel is in place. The panel shall be equipped with non-load bearing dog latches (Presray P/N PRS 831). Each dog shall be equipped with a means for adjusting seal compression after installation in the field.

The mounting frame shall be constructed of structural angle. The edge coaming contacting the panel gasket shall be machined straight and radiused to maximize sealing.

The frame shall be embedded in place at the sill and bolted or welded in place to existing embedments at the sides. A removable diamond plate sill shall be provided for use when the flood panel is removed from the frame and a flush threshold is desired.

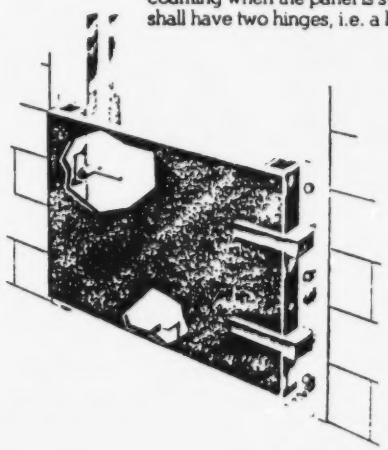
PLFBCG11H FLOOD BARRIERS For New or Existing Construction

Side hinged heavy duty flood panel with compression gasketing and a conversion frame for openings of all sizes.



SPECIFICATION PRESRAY PLFB CG11H

The flood barrier shall be Presray type PLFB CG11H. It shall be designed to resist a maximum ____(to be specified) head of water over its entire span with a minimum safety factor of 2:1 based on the yield strength of the material. The panel shall be constructed of A-36 steel or 6061-T6 aluminum plate. The panel shall include a 20 durometer neoprene (compound No. 3202) compression gasket. The gasket shall be installed in a retaining channel and shall contact a radiused coaming when the panel is swung shut. The panel shall have two hinges, i.e. a lower thrust hinge (Presray P/N PRS 804) and an upper radial hinge (Presray P/N PRS 803). The lower thrust hinge shall be equipped with a bronze oil-impregnated thrust bearing, a stainless steel hinge pin, Grade 5 or better mounting bolts, and a slotted hinge blade (Presray P/N PRS 813) to prevent the hinge from carrying the hydrostatic load. The upper hinge shall have two sealed radially positioned ball bearings, stainless steel hinge pin, slotted blade (Presray P/N PRS 813) and Grade 5 or better mounting bolts. It shall not carry the direct weight of the panel. The panel shall be equipped with non-load bearing dog latches (Presray P/N PRS 831). Each dog shall be equipped with a means for adjusting seal compression after installation in the field.



The mounting frame shall be contstructed of structural angle. The edge coaming contacting the panel gasket shall be machined straight and radiused to maximize sealing. The frame shall allow for bolting or welding to existing embedments. The frame shall provide a rectangular opening with square corners to facilitate easy passage.

Option:

1. The frame can be equipped with a continuously welded subframe suitable for a "pour in place" installation. Stud anchors shall be included and placed at a maximum spacing of 24".

PRESRAY WATERTIGHT DOORS

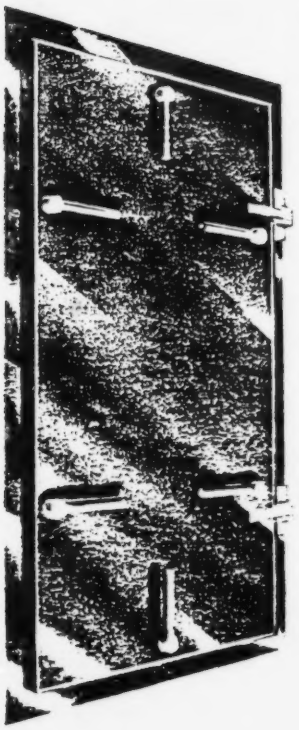
U.S. Patent No. 3,397,490

A Presray watertight door consists of the door panel (either hinged or sliding) with an elastomeric gasket (either inflatable or compression) and a mounting frame with anchors. When the door is closed and secured and the gasket engaged, the door becomes an effective watertight barrier.

Presray Watertight Doors are applicable to both new and existing construction. Presray Watertight Doors are most effective in structures where the main flood problem occurs through entryways of other openings. Flooding in buildings with unsealed foundations will not be prevented, but can be minimized with Presray Watertight Doors.

PRSD3B WATERTIGHT HINGED DOORS
For New or Existing Construction

For installations requiring infrequent access and reliable, repeatable watertight performance.
Standard designs to accommodate water levels up to 25' – specials can be furnished for higher heads.

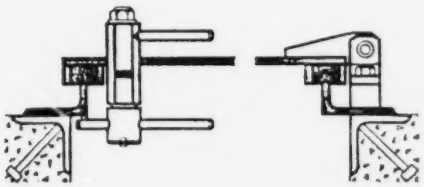


SPECIFICATIONS PRESRAY PRSD3B

GENERAL The watertight door shall be Presray type PRSD3B. It shall be designed with a minimum 2:1 safety factor based on yield and shall provide an effective seal against the design pressure with no visible leakage. The design of the door shall allow the entire hydrostatic pressure on the door to be transmitted to the frame or dogs. The door shall provide a rectangular opening with square corners to facilitate easy passage. When installed true and plumb it shall open and close manually with minimum effort.

DOOR PANEL The door panel shall be constructed of A36 structural steel plate. For standard size doors in the 2'6" x 6'0" to 3'6" x 8'0" range, the plate shall be a minimum of 1/2" thick. The plate shall be straightened as required to insure minimum tolerance buildup with the frame. All welds in the potential "leak path" shall be liquid penetrant inspected in accordance with Appendix VIII of Section VIII Division 1 of ASME Code.

DOOR FRAME AND EMBEDMENT The door frame shall be constructed of A36 structural angle having a minimum thickness of 3/8". The edge coaming contacting the door gasket shall be machined straight and radiused to maximize sealing. The frame shall be equipped with a continuously welded subframe suitable for a "pour in place" installation. Stud anchors shall be included and placed at a maximum spacing of 24". All welds in the potential "leak path" shall be liquid penetrant tested as outlined above. The frame shall overlap the subframe by approximately 1½" on all four sides to provide a locating surface for the dogs.



DOOR HINGES The door shall have two hinges i.e. a lower thrust hinge(Presray P/N PRS804) and an upper radial hinge (Presray P/N PRS803). The lower thrust hinge shall be equipped with a bronze oil-impregnated thrust bearing, a stainless steel hinge pin, Grade 5 or better mounting bolts, and a slotted hinge blade (Presray P/N PRS813) to prevent the hinges from carrying the hydrostatic load. The upper hinge shall have two sealed radially positioned ball bearings, stainless steel hinge pin, slotted blade (Presray P/N PRS813) and Grade 5 or better mounting bolts. It shall not carry the direct weight of the door.

DOOR DOGS Standard door sizes indicated above shall have a minimum of six dogs. The spacing of the dogs shall be such that the loads shall be distributed equally to each. Load bearing dogs shall be made of high strength steel having a minimum yield strength of 130,000 psi. The handle shaft shall be provided with an "O" ring seal and two oil-impregnated bronze flange bearings to maintain shaft alignment. When not in the dogged position, the handles shall be held in the stored position by replaceable stainless steel ball plungers and detents. Each dog shall be equipped with a means for adjusting seal compression after installation in the field.

DOOR GASKETING The door gasket shall be made from Presray 20 durometer neoprene compound No. 3202. The gasket shall be molded rather than extruded. The corner sections shall be fully molded.

DOOR FINISH Standard factory finish shall be one coat of rust inhibitive primer.

CERTIFICATION The supplier shall furnish a certification of leak tightness based on actual tests conducted on this door or a door similar in design to verify that it will withstand the design hydrostatic pressure with no visible leakage.

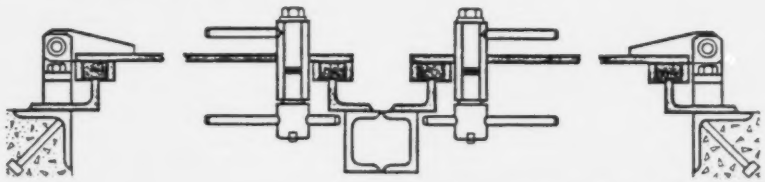
INSTALLATION, OPERATION, AND MAINTENANCE The supplier shall furnish complete installation instructions and operation and maintenance manuals.

OPTIONS

1. If required, the subframe can be omitted to facilitate welding or bolting of the door frame to existing embedments or an equivalent structure.
2. Presray type PRS817 reinforced glass viewing panel.
3. Door Stops and/or Door Holders, consult Presray.

PRSD3BD WATERTIGHT HINGED DOUBLE DOORS
For New or Existing Construction

For installations requiring infrequent personnel access, occasional access for large equipment, and reliable, repeatable watertight performance. Standard designs to accommodate water levels up to 25'—specials can be furnished for higher heads.



SPECIFICATIONS PRS D3BD

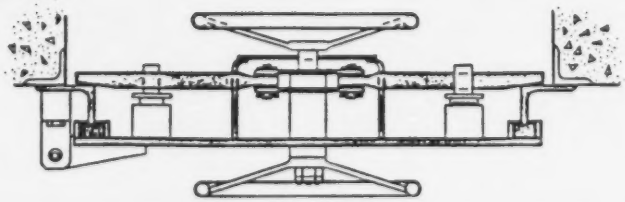
GENERAL The watertight double door shall be Presray type PRSD3BD. It shall be designed with a minimum 2:1 safety factor based on yield and shall provide an effective seal against the design pressure with minimum leakage. The design of the door shall allow the entire hydrostatic pressure on the door to be transmitted to the frame, mullion, or dogs. The door shall provide a rectangular opening with square corners to facilitate easy passage. When installed true and plumb the door panels shall open and close manually with minimum effort.

DOOR PANELS The door panels shall be constructed of A36 structural steel plate. For standard size doors where the individual panels are in the 2'6" x 6'0" to 3'6" x 8'0" range, the plates shall be a minimum of 1/2" thick. The plates shall be straightened as required to insure minimum tolerance buildup with the frame. All welds in the potential "leak path" shall be liquid penetrant inspected in accordance with Appendix VIII of Section VIII Division 1 ASME Code.

DOOR FRAME AND EMBEDMENT The door frame shall be constructed of A36 structural angle having a minimum thickness of 3/8". The edge coaming contacting the door gasket shall be machined straight and radiused to maximize sealing. The frame shall be equipped with a continuously welded subframe suitable for a "pour in place" installation. Stud anchors shall be included and placed at a maximum spacing of 24". All welds in the potential "leak path" shall be liquid penetrant inspected as outlined above. The frame shall overlap the subframe by approximately 1½" on all four sides to provide a locating surface for the dogs.

PRSD3BHW WATERTIGHT QUICK ACTING HINGED DOORS
For New or Existing Construction

For installations requiring frequent access and reliable, repeatable watertight performance. Standard designs to accommodate water levels up to 20'—specials can be furnished for higher heads.



SPECIFICATIONS PRESRAY PRSD3BHW

GENERAL The watertight door shall be Presray type PRSD3BHW. It shall be designed with a minimum 2:1 safety factor based on yield and shall provide an effective seal against the design pressure with no visible leakage. The design of the door shall allow the entire hydrostatic pressure on the door to be transmitted to the frame or dogs. The door shall provide a rectangular opening with square corners to facilitate easy passage. When installed true and plumb it shall open and close manually with minimum effort.

DOOR PANEL The door panel shall be constructed of A36 structural steel plate. For standard size doors in the 2'6" x 6'0" to 3'6" x 8'0" range, the plate shall be a minimum of 1/2" thick to withstand heads of water up to 20' from the hinge side The plate shall be straightened as required to insure minimum tolerance buildup with the frame. All welds in the potential "leak path" shall be liquid penetrant inspected in accordance with Appendix VIII of Section VIII Division 1 of ASME Code.

DOOR FRAME AND EMBEDMENT The door frame shall be constructed of A36 structural angle having a minimum thickness of 3/8". The edge coaming contacting the door gasket shall be machined straight and radiused to maximize sealing. The frame shall be equipped with a continuously welded subframe suitable for a "pour in place" installation. Stud anchors shall be included and placed at a maximum spacing of 24". All welds in the potential "leak path" shall be liquid penetrant tested as outlined above. The frame shall overlap the subframe by approximately 1½" on all four sides to provide a locating surface for the dogs.

DOOR HINGES The door shall have two hinges i.e. a lower thrust hinge (Presray P/N PRS804) and an upper radial hinge (Presray P/N PRS803). The lower thrust hinge shall be equipped with a bronze oil-impregnated thrust bearing, a stainless steel hinge pin, Grade 5 or better mounting bolts

CENTER MULLION Door edges at the center of the opening are to be supported by a removable mullion to minimize deflection. Coaming for the door gaskets shall be positioned on the mullion to line up with the coaming around the outer door edges to maximize seal continuity. Presray type PR4275 molded elastomeric closure shall be used to effect the seal between mullion and sill.

DOOR HINGES (Identical to door hinges specification on type PRSD3B door.)

DOOR DOGS (Identical to door dogs specification on type PRSD3B door.)

DOOR GASKETING (Identical to door gasketing specification on type PRSD3B door.)

DOOR FINISH (Identical to door finish on PRSD3B door.)

CERTIFICATION The supplier shall furnish a certification of leak tightness based on actual tests conducted on this door or a door similar in design to verify that it will withstand the design hydrostatic pressure with minimum leakage.

INSTALLATION, OPERATION AND MAINTENANCE The supplier shall furnish complete installation instructions and operation and maintenance manuals.

OPTION

1. If required, the subframe can be omitted to facilitate welding or bolting of the door frame to an existing subframe or an equivalent structure.
2. Door Stops and/or Door Holders, consult Presray.

and a slotted hinge blade (Presray P/N PRS813) to prevent the hinges from carrying the hydrostatic load. The upper hinge shall have two sealed radially positioned ball bearings, stainless steel hinge pin, slotted blade (Presray P/N PRS813) and Grade 5 or better mounting bolts. It shall not carry the direct weight of the door.

HAND WHEEL OPERATED LATCHING MECHANISM The door-latching operation is to be accomplished with minimum effort and time by the turning of a handwheel. The handwheel shall throw six dogs. Each dog shall be adjustable as to stroke length and position to provide maximum adjustment for seal compression.

DOOR GASKETING The door gasket shall be made from Presray 20 durometer neoprene compound No. 3202. The gasket shall be molded rather than extruded. The corner sections shall be fully molded.

DOOR FINISH (Identical to door finish on PRSD3B door.)

CERTIFICATION The supplier shall furnish a certification of leak tightness based on actual tests conducted on this door or a door similar in design to verify that it will withstand the design hydrostatic pressure with no visible leakage.

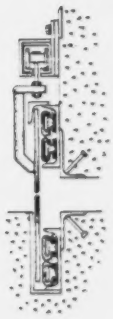
INSTALLATION, OPERATION AND MAINTENANCE The supplier shall furnish complete installation instructions and operation and maintenance manuals.

OPTION

1. If required, the subframe can be omitted to facilitate welding or bolting of the door frame to existing embedments or an equivalent structure.
2. Door Stops and/or Door Holders, consult Presray.

PRSD5B WATERTIGHT SLIDING DOOR with Pneuma-Seal Inflatable Gasket

Can be installed with a recess at the sill to facilitate personnel traffic and equipment passage.



For New or Existing Construction

SPECIFICATIONS PRSD5B

GENERAL The watertight door shall be Presray type PRSD5B. It shall be designed with a minimum 2:1 safety factor based on yield and shall provide an effective seal against the design pressure with no evident leakage. It shall be capable of being operated manually from either side.

DOOR PANEL The door panel shall be A36 structural steel plate with a 63 microinch finish on the sealing surface. All welds in the potential "leak path" shall be liquid penetrant inspected in accordance with Appendix VIII, Section VIII Division 1 ASME Code.

FRAME AND SUBFRAME The door frame shall be A36 structural steel channel welded to an A36 structural angle subframe with stud anchors suitable for a "pour in place" installation. The frame shall include suitable provisions for continuous support of all four edges of the door when the door is in the closed position.

The frame at the sill shall form a trench to be recessed in the floor; the back wall of the trench shall provide a surface on which to mount the inflatable seal; the front wall shall act as a stop and provide a continuous support for the bottom edge of the door.

SEALS The door seals shall be Presray type I Pneuma-Seal inflatable gaskets of a material suitable for the intended environment. They shall be continuous around all four sides of the opening, and be mechanically attached to the frame.

SEAL CONTROLS A Presray type PR5200 control assembly including four-way valve, pressure regulator, check valve, pressure gauge, and stainless steel mounting panel shall be provided for wall mounting on both the exterior and interior walls to enable sealing and unsealing of the door from either side.

HARDWARE Sliding door hardware to be supplied shall include trolley track, mounting brackets, ball bearing hangers, and door pulls.

FINISH Door and frame shall be furnished with one factory applied prime coat (see options).

CERTIFICATION The manufacturer shall furnish a certification of leak tightness based on actual tests conducted on this door, or a door similar in design, to verify that it will withstand the design pressure with no evident leakage.

INSTALLATION, OPERATION AND MAINTENANCE The manufacturer shall furnish complete installation instructions and operation and maintenance manuals.

OPTIONS

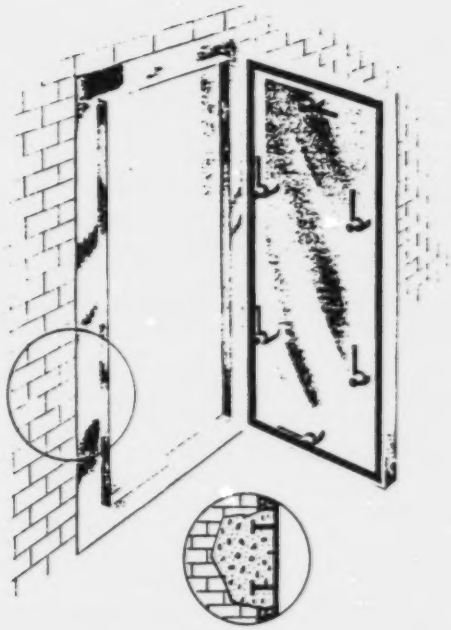
1. Alternate door panel and frame materials: aluminum (painted or anodized), stainless steel.
2. Presray type PRS817 viewing panel.
3. Raised threshold in lieu of slot in floor.

INSTALLATION

All Presray Flood Protection Products are shipped with concise instruction and maintenance manuals. Installation is usually straightforward and in keeping with standard construction practice. Typical installations are illustrated below. User should consult the installation manuals and the applicable detail drawings prior to installation.

For unusually large or complex installations user may request the services of a Presray field erection engineer.

Typical Installation In Existing Construction



Typical Installation In New Construction

INFLATING PNEUMA-SEALS®

Pneuma-Seals may be inflated from any of the following sources:

– Hand or foot operated air pump

– Portable air compressor

– Portable air tank (2 gallons or larger)

– Bottled gas (CO_2 or N_2) if equipped with a pressure reducing regulator.

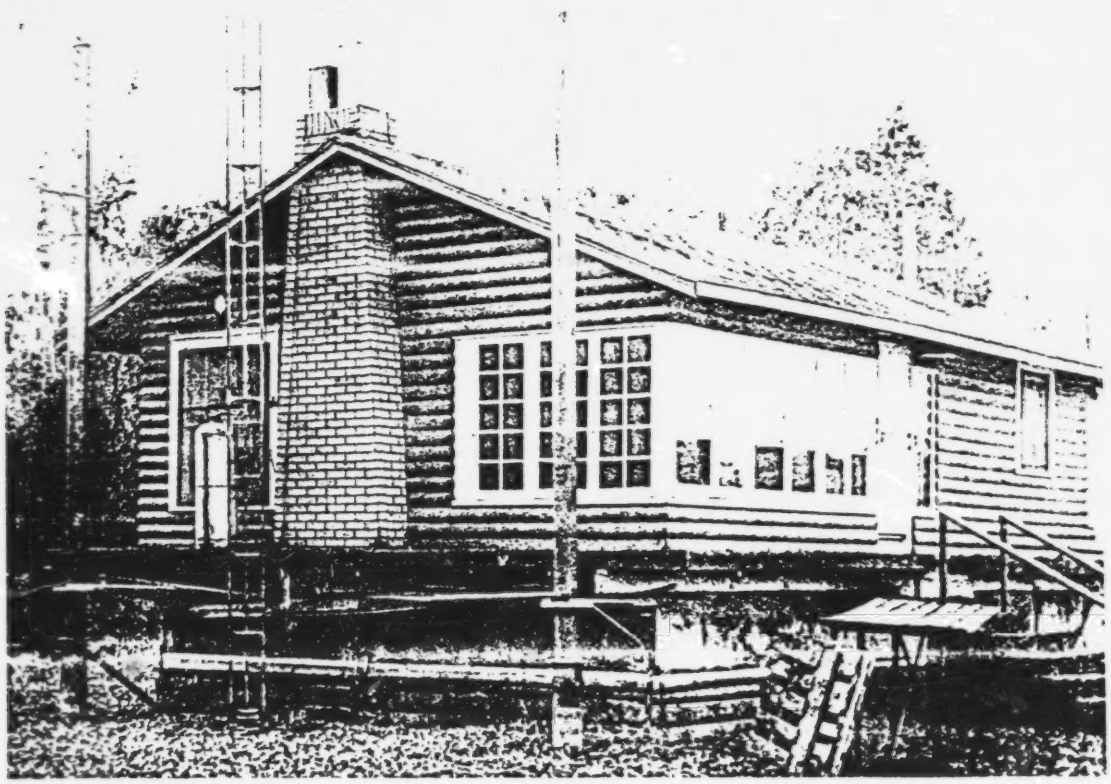
– Shop air (non-oiled and filtered)

Typically Flood Barriers come equipped with an automotive type tire valve and Watertight Doors come equipped with threaded pipe connections. When installing Flood Barriers in locations where shop air is not available the use of a hand or foot pump is recommended. Typically a three foot by two foot high PLFB111 Flood Barrier would require approximately 8 pump activations for inflating each seal. Operating pressures are typically 25-50 PSIG for most doors and flood barriers. On request Presray can also design and furnish custom air systems for remote operation, automatic control and monitoring.

One-story house mounted on a barge-like flotation system, Ouachita River, Arkansas

Flooding from the Ouachita River in the vicinity of this structure occurs on an almost annual basis and can last from several weeks to 6 months. Damage to a structure inundated this frequently and for this length of time could be devastating. To avoid such a dilemma, this one-story conventional frame house was mounted on a barge-like flotation system attached by collars to four metal guide pylons anchored in the ground at each corner (Figure A44). When the area is not flooded, the barge rests on a concrete foundation that is hidden by wooden aprons attached to the sides of the barge. When flooding occurs, the structure rises vertically with the water, guided by the pylons. Water and sewage hookups are made of flexible pipe and are serviceable during flooding. The estimated cost of flood proofing is $6000.

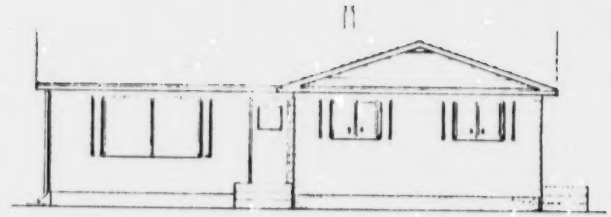
This system of flood proofing appears to work well in areas of relatively deep flooding of long duration with nondamaging flow velocities. During the 1973 flood, floodwaters reached 15 feet in depth with no failure to the system. Aside from the relatively high cost of the system, however, is the fact that maintenance is required to keep the barge apparatus from deteriorating. The owner indicated that if he were to build again, he would likely use styrofoam pontoons in lieu of the metal barge.



(reference 14)

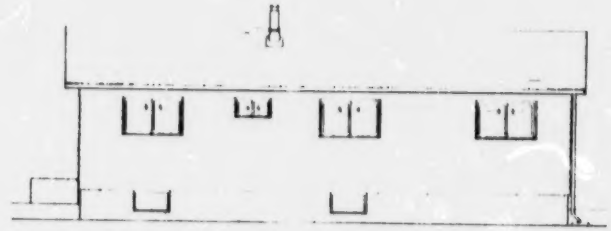
APPENDIX G: ALBERTA HOUSE COST COMPARISON STUDY PROTOTYPE

LEFT ELEVATION



FRONT ELEVATION

RIGHT ELEVATION

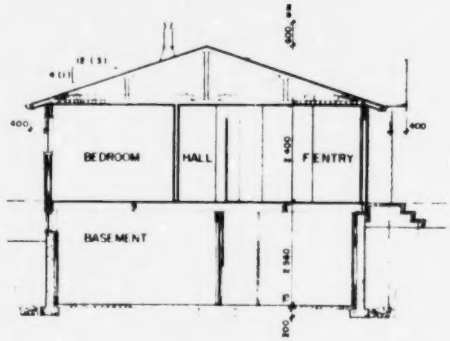


REAR ELEVATION

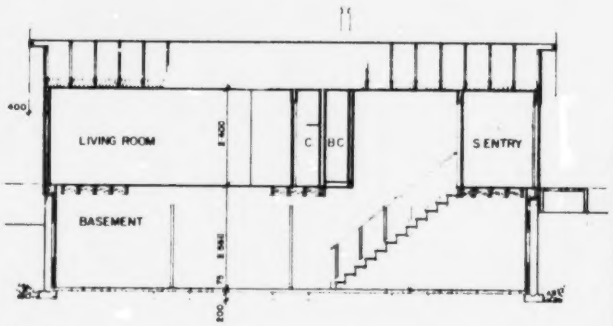
ALBERTA HOUSE COST COMPARISON STUDY

ELEVATIONS

SCALE 1:50



SECTION A



SECTION B

EXTERIOR WALLS

PREFINISHED ALUMINUM SIDING
ALUMINUM FACE BUILDING PAPER
9mm EXT. GRADE PLYWOOD SHEATHING
38 x 89mm WOOD STUDS @ 400mm O.C.
R12 OR BETTER INSULATION
0.10 MIL POLY VAPOUR BARRIER
12mm GYPSUM BOARD TAPED AND LAYERED

BASEMENT WALLS

200mm CONCRETE
REINFORCED
0.10 MIL POLY VAPOUR BARRIER
38 x 140mm WOOD STRAPPING AT 400mm O.C.
R12 BATT INSULATION
12mm GYPSUM BOARD TAPED AND SANDED
PAINT
CONCRETE FOOTING WITH KEY
19mm DIAMETER PERFORATED WEEPING PIPE
400mm MIN. CRUSHED GRAVEL COVER

NOTE:

THE DAMP PROOFING SHALL EXTEND FROM THE BASEMENT FLOOR AND SHALL TERMINATE AT GRADE LEVEL

NO MEMBRANE SHALL BE APPLIED ABOVE GRADE LEVEL BETWEEN THE INSULATION AND THE FOUNDATION WALL

FLOORS

GROUND

9mm PLYWOOD SHEATHING SUB FLOOR
12mm PLYWOOD SHEATHING SUB FLOOR
UNDERLAY
38 x 235mm FLOOR JOISTS @ 400mm O.C.
R20 MINIMUM CELLULOSE INSULATION TO ATTIC
0.10 MIL POLY VAPOUR BARRIER
12mm GYPSUM BOARD CEILING

ROOF

ASPHALT SHINGLES
12mm EXT. GRADE PLYWOOD SHEATHING
ASPHALT TRUSSES @ 400mm O.C.
38 x 89mm NO. 2 GRADE FIR OR BETTER
R50 MINIMUM CELLULOSE INSULATION TO ATTIC
0.10 MIL POLY VAPOUR BARRIER
12mm GYPSUM BOARD CEILING

FASCIA

25 x 150mm SPRUCE BOARD PREFINISHED ALUMINUM

SOFFIT

PREFINISHED ALUMINUM PERFORATED

EAVESTROUGH

PREFINISHED ALUMINUM GA. 57mm WITH FITTINGS

DOWNSPOUT

PREFINISHED ALUMINUM GA. 57mm CORRUGATED RECTANGULAR WITH FITTINGS

FLASHINGS

GALVANIZED STEEL GA. 457mm AT EAVES, VALLEYS, VENTS, ETC.

STAIRS

FRONT STEPS

PRECAST CONCRETE WITH SUPPORTING BRACKETS
1240 x 1500 x 600mm 5 RISERS

SIDE STEPS

PRECAST CONCRETE WITH SUPPORTING BRACKETS
1270 x 1075 x 600mm 5 RISERS

BASEMENT

38 x 235mm STRINGERS
38 x 235mm TREADS
9.5mm PLYWOOD RISERS
38mm DIAMETER PIPE HANDRAIL WITH BRACKETS

MECHANICAL NOTES

1. ALL GAS FIRED APPLIANCES SHALL BE INSTALLED IN ACCORDANCE WITH "THE GAS PROTECTION ACT AND REGULATIONS PERSUANT TO THAT ACT"
2. PROVIDE ADEQUATE COMBUSTION AIR FOR GAS FIRED FURNACE
3. ALL DUCTWORK SHALL BE GALVANIZED STEEL IN ORDINANCE WITH CODE
4. PROVIDE FRESH AIR INTAKE FROM OUTDOORS WITH SUITABLY SIZED FRESH AIR GRILLE AND CONNECT TO COLD RETURN AIR DUCT UPSTREAM OF FURNACE CIRCULATING FAN
5. ALL HEATING EQUIPMENT SHALL BE SIZED TO MAINTAIN A TEMPERATURE OF +22°C INSIDE AT MAIN FLOOR WHEN OUTSIDE TEMPERATURE IS -36°C. THE BASEMENT TEMPERATURE MAY BE HELD AT +18°C

NOTES

1. PROVIDE 560 x 760mm LOCKABLE PLYWOOD HATCHWAY
2. APPLY FLASHING, TUCK WITH, OVER ALL EXTERIOR WALL OPENINGS.
3. UNOBSTRUCTED VENT AREA OF NOT LESS THAN 1:150 OF INSULATED CEILING AREA
4. ANCHORAGE SHALL BE PROVIDED BY EMBEDDING THE ENDS OF THE FIRST FLOOR JOISTS IN CONCRETE OR FASTENING THE STEEL PLATE TO THE FOUNDATION WITH NOT LESS THAN 12.7mm DIAMETER ANCHOR BOLTS SPACED NOT MORE THAN 2.4m O.C. SUCH ANCHOR BOLTS SHALL BE EMBEDDED NOT LESS THAN 100mm IN THE FOUNDATION AND SO DESIGNED THAT THEY MAY BE TIGHTENED WITHOUT WITHDRAWAL THEM FROM THE FOUNDATION.
5. PROVIDE 38 x 38mm CROSS BRACING OF 19 x 64mm CONTINUOUS BRACES AT MID SPAN OR FLOOR JOISTS
6. APPLY 0.15mm POLYTHYLENE AT SOFFEES, EXTENDING FROM EDGE OF WALL 914mm UP ROOF SLOPE
7. 12mm PLYWOOD WALL SHEATHING MAY BE USED AS AN ALTERNATIVE TO 19mm PLYWOOD (SEE NOTE 3 IF ALL EDGES ARE SUPPORTED)
8. EAVESTROUGH AND DOWNSPOUTS SHALL CONFORM TO THE REQUIREMENTS OF SUBSECTION 9.27.15 OF THE ALBERTA BUILDING CODE
9. ALL ELECTRICAL FACILITIES SHALL COMPLY WITH SUBSECTION 9.34.15 OF THE ALBERTA BUILDING CODE WHERE APPLICABLE

ALBERTA HOUSE COST COMPARISON STUDY

SECTIONS

SCALE 1:50

0 .5 1 2 3 4 5 6m

APPENDIX H

Alberta Home Mortgage Corporation

Policies and Procedures for

Lending/Insuring in Floodplains

Approved: 1986 01 28

ALBERTA MORTGAGE AND HOUSING CORPORATION
POLICIES AND PROCEDURES
LENDING/INSURING IN FLOODPLAINS

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3. POLICIES

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- 3.3 NEW DWELLINGS ABOVE THE DESIGN FLOOD ELEVATION
- 3.4 EXISTING DWELLINGS ABOVE THE DESIGN FLOOD ELEVATION

4. PROCEDURES

5. TECHNICAL GUIDELINES

- 5.1 NEW DWELLINGS ABOVE THE DESIGN FLOOD ELEVATION
- 5.2 EXISTING DWELLINGS ABOVE THE DESIGN FLOOD ELEVATION

ALBERTA MORTGAGE AND HOUSING CORPORATION
POLICIES AND PROCEDURES
LENDING/INSURING IN FLOODPLAINS

1. PREAMBLE

Floodplains are regions adjacent to a river which is subject to periodic flooding. The frequency which a flood may occur is illustrated by a return period. For example, a 1 in 50 year flood implies that, on the average, the area is estimated to flood once every 50 years. A 1 in 100 year return period flood would be a more severe flood. It is possible, for example, for a 1 in 50 year flood to occur 2 years in a row and then not occur in the next 100 years.

"Open water" floods are those resulting from excessive rainfall, run-off, intensity or duration of storms often combined with saturated ground conditions. "Ice jam" floods are floods created due to ice floes clogging the river backing up water along the channel. In some communities (especially those with rivers flowing toward the north) the ice jam flood at a lesser return period may be much more severe than an open water flood of a larger return period (for example a 1 in 25 year ice jam flood may be much more severe than a 1 in 100 year open water flood).

Maps illustrating the 1 in 100 year flood elevation and flooded area have been prepared for select communities in Alberta. Delineation of floodplains for a particular return period is often done using a combination of aerial photographs, high water marks, residents' recollections etc. Accuracy of flood boundaries is therefore prone to error plus changes in the river regime created due to structures (bridges, culverts, etc) clearing of land, recent development of land etc make precise mapping of flood plain boundaries difficult. AMHC has chosen therefore to consider areas which are 300mm above the 1 in 100 year flood elevation adjacent to rivers to be of concern.

ALBERTA MORTGAGE AND HOUSING CORPORATION
POLICIES AND PROCEDURES
LENDING/INSURING IN FLOODPLAINS

Figure #1 illustrates some of the concepts outlined on page #2

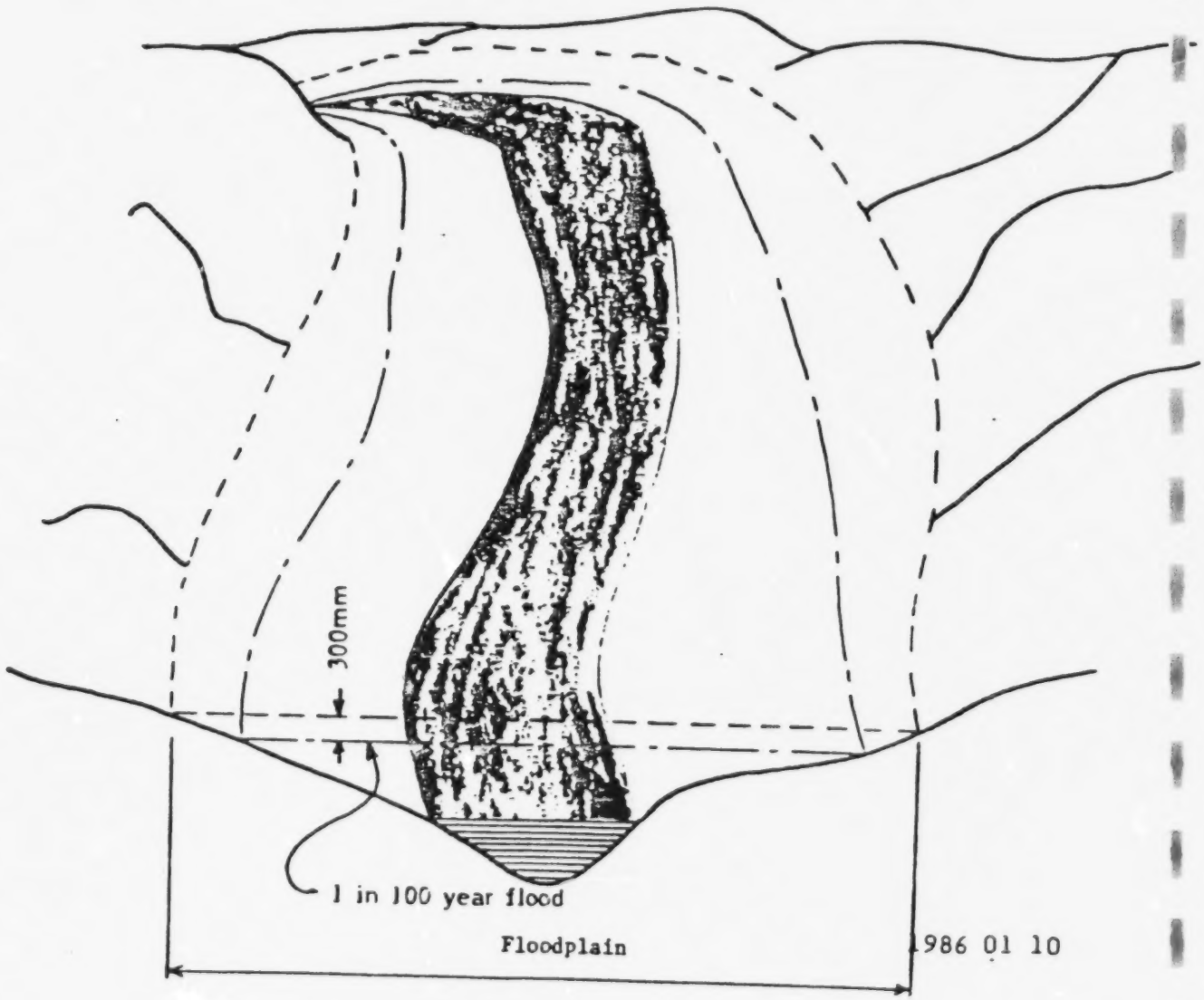

FIGURE 1

ALBERTA MORTGAGE AND HOUSING CORPORATION
POLICIES AND PROCEDURES
LENDING/INSURING IN FLOODPLAINS

With respect to the structure (generally a dwelling), the reference elevation is the lowest wooden structural member of the main floor system. Whereas this could be the lowest elevation of the first floor joist, beam or sill, typically it will be the bottom of the beam supporting the floor joist (see Figure #2 below).

For dwellings without heated basements or heated crawl spaces (such as mobile homes) where insulation protrudes below the lowest wooden structural member of the first floor, the lowest insulation level should be deemed the dwelling elevation.

Any municipal bylaws/building codes etc. which are more restrictive than those outlined in this document shall govern (i.e. project to meet all local codes and bylaws).

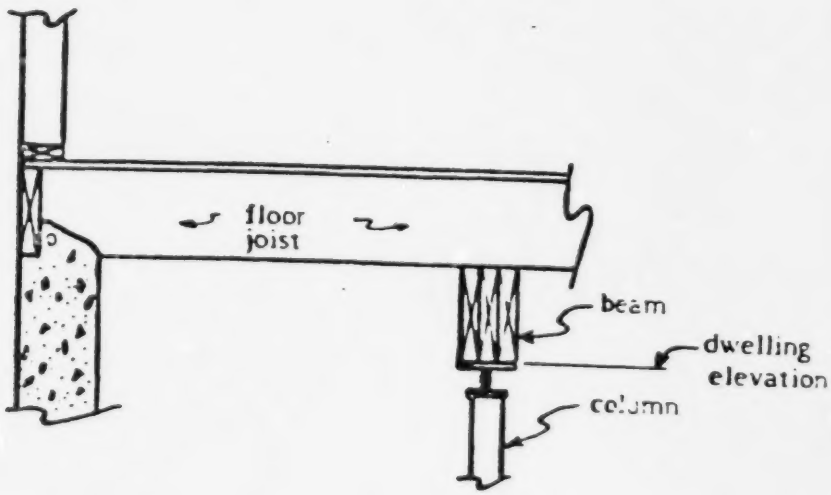

FIGURE 2

ALBERTA MORTGAGE AND HOUSING CORPORATION
POLICIES AND PROCEDURES
LENDING/INSURING IN FLOODPLAINS

2. DEFINITIONS

2.2 Design Flood Elevation: the 1 in 100 year open water flood elevation (——— - ——— on Figure #1) or the 1 in 25 year ice jam flood elevation whichever is greater.

2.1 Floodplain: the area inundated to the design flood elevation plus 300mm vertically above the design flood elevation (— — — — —on Figure #1).

2.3 Dwelling elevation: the underside of lowest wooden structural member or insulation of the main (first floor) system (see Figure #2).

ALBERTA MORTGAGE AND HOUSING CORPORATION
POLICIES AND PROCEDURES
LENDING/INSURING IN FLOODPLAINS

3. POLICIES

3.1 GENERAL

Whereas the general policy is AMHC does not want to lend/insure in Flooodplains, it is recognized that certain communities are in low lying areas hence lending/insuring may be undertaken at the discretion of the Corporation subject to certain limiting conditions.

3.2 DWELLINGS BELOW THE DESIGN FLOOD ELEVATION

AMHC will not lend/insure where the dwelling elevation is below the Design Flood Elevation unless approval is obtained from the Vice President, Mortgage Lending Division.

3.3 NEW DWELLINGS ABOVE THE DESIGN FLOOD ELEVATION

AMHC may lend/insure new dwellings within Floodplains where the dwelling elevation is above the Design Flood Elevation, is subject to one of the three following alternatives and that conditions are met as further illustrated in the attached technical guidelines:

3.3.1 Provide enough suitable fill to ensure all components of the structure (including the top of basement floor drain grates, where applicable) are above the design flood elevation.

3.3.2 Raise the building on posts, piles or piers.

3.3.3 Intentionally design the structure to permit the basement to be flooded.

ALBERTA MORTGAGE AND HOUSING CORPORATION
POLICIES AND PROCEDURES
LENDING/INSURING IN FLOODPLAINS

3.4 EXISTING DWELLINGS ABOVE THE DESIGN FLOOD ELEVATION

AMHC may lend/insure existing dwellings within the Floodplain where the dwelling elevation is above the Design Flood Elevation subject to conditions outlined in the attached technical guidelines. As in 3.3, the three alternatives are:

3.4.1 The existing structure is high enough so that all components of the structure (including the top of the basement floor drain grates where applicable) are above the design flood elevation.

3.4.2 The dwelling is elevated by posts, piles or piers.

3.4.3 The dwelling is intentionally constructed to permit the basement to be flooded.

1986 01 10

ALBERTA MORTGAGE AND HOUSING CORPORATION
POLICIES AND PROCEDURES
LENDING/INSURING IN FLOODPLAINS

4. PROCEDURES

4.1 Loans Officers receiving applications shall cross check the location of the dwelling with the Floodplain map. If no map is available:

a) if it is beyond a reasonable distance from the river and above other structures (e.g. bridges, roadways, etc) process the application as per normal procedures.

b) if the location is within an area suspected to be a Floodplain, contact a member of Consulting Services (Engineering or Inspection and Property Repair). Consulting Services will decide if the location is within a Floodplain or not and advise the Loans Officer accordingly.

4.2 If 4.1 reveals the dwelling is within the Floodplain, the applicant should be advised of approximately 2 weeks additional processing time required. A copy of sections 1, 2, 3 and 5 of this document will be forwarded to him advising that depending upon which alternative is chosen, additional information and professional certification may be required.

4.3 Forward the application to Inspection and Property Repair who will determine the dwelling elevation, compare it with the Flood Area map elevation (if available) and review the application specifically for conformance to the policies outlined in this document.

4.4 Review is routed to the Area Manager of Inspection and Property Repair for comments and recommendations and then to the Director of Lending for approval.

ALBERTA MORTGAGE AND HOUSING CORPORATION
POLICIES AND PROCEDURES
LENDING/INSURING IN FLOODPLAINS

4.5 The Director of Lending returns the application to the Loans Officer advising:

a) the dwelling conforms to AMHC policy, the Loans Officer advises the applicant and the application is processed as per normal procedures; or

b) the dwelling does not conform to AMHC policy wherein the Loans Officer returns the application along with the comments.

4.6 Should the applicant be denied a mortgage based upon this policy and choose to submit revised plans etc. perform steps 4.3 to 4.5 inclusive.

ALBERTA MORTGAGE AND HOUSING CORPORATION
POLICIES AND PROCEDURES
LENDING/INSURING IN FLOODPLAINS

5. TECHNICAL GUIDELINES

5.1 NEW DWELLINGS ABOVE THE DESIGN FLOOD ELEVATION

AMHC may lend/insure new dwellings located within the Floodplain where the dwelling elevation is above the Design Flood Elevation provided one of the following three alternatives (and accompanying conditions) is satisfied:

5.1.1 Provide enough rock or compacted earthen fill to insure all components of the structure including the top of the basement floor drain grates (where applicable) is above the Design Flood Elevation.

5.1.1.1 Site elevations must be compatible with surrounding areas/structures.

5.1.1.2 The application shall include the original ground elevation (certified by an Alberta land Surveyor) and the dwelling elevation (see 2.3).

5.1.1.3 Structures founded on soils prone to capillary water rise (silts) shall contain a water cut-off unless the lowest portion of the structure is above an elevation equal to the design flood elevation plus the estimated capillary rise. Where requested, the applicant shall provide soil identification test results and an estimate of capillary rise of the underlying soils certified by a Professional Engineer registered in the Province of Alberta. Should the estimated capillary rise place moisture above the lowest point of thestructure, a proposed water cut-off shall be illustrated.

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5.1.1.4 Particular attention should be paid to satisfy the requirements of section 4.2 of the 1985 Alberta Building Code.

5.1.1.5 Ground slope shall not exceed 1 vertically in 30 horizontally for a distance of 4.5m from the structure and 1 vertically in 4 horizontally thereafter.

5.1.1.6 Units serviced by wells must have the required casing extended at least 150mm above the design flood elevation if the well is vented or seal the casing at the top.

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5.1.2 Raise the dwelling on posts, piles or piers so the bottom of the lowest wooden joist, beam, or sill or building insulating material (i.e. the dwelling elevation) is above the Design Flood Elevation.

5.1.2.2 No basements, active crawl spaces, appliances or storage spaces shall be permitted in the region between the dwelling elevation and the finished ground elevation.

5.1.2.3 The entire system (foundation and building) must be designed to withstand all loads and influences and shall be certified by a Professional Engineer or Architect registered in the Province of Alberta.

5.1.2.4 The applicant shall provide the original ground elevation (certified by an Alberta Land Surveyor) and the dwelling elevation.

5.1.3 Allow the basement to be flooded to permit equalization of hydrostatic pressure on each side of the foundation wall during a flood.

5.1.3.1 The applicant shall provide the original ground elevation (certified by an Alberta Land Surveyor) and the dwelling elevation.

5.1.3.2 All structural members below the dwelling elevation shall be capable of resisting water damage.

5.1.3.3 Crawl spaces and other difficult to clean spaces shall not be permitted.

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5.1.3.4 Footings, foundation walls and basement floors shall be cast in place Portland cement concrete (i.e. preserved wood foundation systems not permitted).

5.1.3.5 All components of the dwelling shall be anchored to prevent hydrostatic uplift and lateral movement of the structure (i.e. joist embedded in concrete or joist/headers attached by anchor bolts or equivalent).

5.1.3.6 Basement insulating material shall be installed on the outside of the structure, shall be rigid, easily cleaned, and fastened to prevent detachment during flooding.

5.1.3.7 The system shall be designed and certified by a Professional Engineer or Architect registered in Alberta.

5.1.3.8 The clear height from the top of the basement concrete floor slab to the underside of the first storey floor system including beams must not be less than 1930mm.

5.1.3.9 Basements must have at least 2 openable windows. The top of the window sills must be no higher than 150mm below grade.

5.1.3.10 Basement walls and floors must not have any finishing materials covering the concrete.

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5.1.3.11 Basements must not contain habitable space or be used for the storage of immovable objects or hazardous materials that are buoyant, flammable, explosive or toxic.

5.1.3.12 Columns supporting the first storey floor shall be steel.

5.1.3.13 Load bearing walls constructed below the first storey floor shall be cast in place concrete.

5.1.3.14 Suitable anchorage of exterior walls to slabs on grade must be provided.

5.1.3.15 A covered sump pit with a removable automatic submersible pump must be provided in all basements.

5.1.3.16 The sump pump must discharge above the design flood elevation. A ground fault interceptor separate electrical circuit must be provided for the sump pump and the operating switch must be located above the design flood elevation.

5.1.3.17 The sump pump may be connected to a municipal storm sewer but must not be connected to a municipal sanitary sewerage system.

5.1.3.18 Granular material under the basement slab should be sloped so that the entire area is drained to the sump pit.

5.1.3.19 Basement floor slabs must have a slope toward the floor drain.

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5.1.3.20 A backwater valve(s) shall be installed on the sanitary sewerage service and the storm sewerage service (if applicable). Floorains or Flovalves may be used as an alternate. These valves must be accessible for cleaning and inspection.

5.1.3.21 Sanitary sewerage connections for plumbing facilities must not be installed below the Design Flood Elevation.

5.1.3.22 Central heating units such as oil, gas or electric forced air furnaces, including all duct work, boilers and hot water heaters shall not be installed below the Design Flood Elevation.

5.1.3.23 Electrical service panels must be located above the Design Flood Elevation. Electrical circuits serving areas below the Design Flood Elevation must be on separate circuits of ground fault interceptor design.

5.1.3.24 Hot and cold water taps shall not be located below the Design Flood Elevation.

5.1.3.25 Basement windows shall be designed to be openable to permit entrance of water through them during a flood and shall not be impeded by covering or sealing devices.

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5.2 EXISTING DWELLINGS ABOVE THE DESIGN FLOOD ELEVATION

AMHC may lend/insure existing dwellings located within the Floodplain Area where the dwelling elevation is above the Design Flood Elevation subject to the following conditions:

5.2.1 The applicant shall include the original ground elevation (certified by an Alberta Land Surveyor) and the dwelling elevation.

5.2.2 There must not be any evidence of previous flooding in the life of the structure.

5.2.3 All electrical circuits below the Design Flood Elevation must be ground fault interceptor protected.

5.2.4 Backwater valves must be present on the sanitary and, if applicable, storm sewerage services.

5.2.5 Footings, foundation walls and basement floors shall be cast in place Portland cement concrete.

5.2.6 Basement areas must be accessible and easily cleaned.

5.2.7 Provision shall be made to prevent hydrostatic uplift and lateral movement (during a flood) by anchorage of joist ends in the cast in place concrete or anchoring joists or headers to cast in place concrete walls by anchor bolts or equivalent.

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5.2.8 Rain water downspouts that are connected to a municipal storm sewerage system shall have overflows located above the Design Flood Elevation.

5.2.9 The lending/insured value shall not include any improvements to basements which could be damaged by flooding.

5.2.10 The Occupancy Permit must be issued prior to January 1, 1986.

5.2.11 In addition to normal insurance requirements, flood insurance, with the deductible of not more than $2,000.00 and an insured value of not less than 50% of the replacement value, shall be provided by the applicant (with loss payable to AMHC) prior to execution of the mortgage documents.

APPENDIX I: DEFINITIONS

Backwater Effect - The rise in water surface elevation caused by some obstruction such as a narrow bridge opening, buildings or fill material that limits the area through which the water must flow.

Base Flood Plain - The flood plain that would be inundated by a 100-year (one-percent chance) flood.

Basement Floor - The lowest floor level below the main floor of a building.

Channel - A natural or artificial watercourse with definite bed and banks to confine and conduct flowing water.

Channel Capacity - The maximum flow which can pass through a channel without overflowing the banks.

Design Flood Level (DFL) - The level which would result from the high water of record. In Alberta, this is the 100 year flood level or one-percent chance flood level. It is used to indicate the minimum flood elevation to be used by a community as a basis for it's flood plain management regulation. Often referred to in literature as the Base Flood Elevation.

Designated Flood Plain - The flood plain boundary delineated by the design flood level.

Design Flood - Commonly used to mean the magnitude of flood used for design and operation of flood control structures or other protective measures. It is sometimes used to denote the magnitude of flood used in flood plain regulations.

Elevation - Distance above the natural boundary of the waterbody, above natural ground elevation, or above mean sea level.

Erosion - The process of the gradual wearing away of land masses due to friction forces created between flowing water and the ground surface.

First Floor - The floor which is level with or immediately above the main point of entry into the building. For residences, it is normally that floor which comprises the main living area of the dwelling.

Flood Or Flooding - Temporary inundation of normally dry land areas caused by overflow from an unusual and rapid accumulation or runoff of surface waters from any source including rivers, streams, lakes or other bodies of standing water. The rise in water may be caused by excessive rainfall, snowmelt, natural stream blockages, wind storms over a lake or any combination of such conditions.

Flood Construction Level (FCL) - The DFL plus a variable allowance for Freeboard. Used to establish the minimum elevation of the underside of the floor system for habitable buildings. It also generally establishes the height of the top of any berms or levees. CMHC requires 300 mm minimum freeboard.

Flood Crest - The maximum stage or elevation reached or expected to be reached by the waters of a specific flood at a given location.

Floodplain - Any normally dry lowland area, whether diked or not, which by reason of elevation is susceptible to flooding from an adjoining watercourse, ocean, lake, or other body of water, including the sea.

Flood Risk Map - An official map of a community issued by the province on which the boundaries of the flood plain (i.e., subject to the 100-year flood), or flood-related erosion areas having special hazards have been drawn.

Flood Plain Regulations - A general term for the full range of codes, ordinances, and other regulations relating to the use of land and construction within stream channels and flood plain areas. The term encompasses zoning ordinances, subdivision regulations, building and housing codes, encroachment line statutes, open-space regulations, and other similar methods of control affecting the use and development of these areas.

Flood Proofing - Any combination of structural and nonstructural additions, changes, or adjustments to properties and structures which reduce or eliminate flood damage to lands, water and sanitary facilities, structures, and contents of buildings.

Floodway - The channel of a watercourse and those portions of the adjoining flood plain required to provide for the passage of a selected flood (normally the 100-year flood) with an insignificant increase in the flood levels above that of natural conditions.

Freeboard - A distance or factor of safety above the DFL as determined by the regulatory authority. Unless stated otherwise, freeboard is a minimum of 300 mm (1 foot). (It is used to compensate for many unknown factors which could contribute to flood heights greater than anticipated as well as wave action, surge, floating debris, etc.)

Habitable Area - Any room or space within a building or structure which is or can be used for human occupancy, furnaces and other fixed equipment or storage of goods or possessions damageable by floodwaters.

Floodway - The channel of the watercourse and the portion of the floodplain which is reasonably required to carry and discharge floodwaters of a designated magnitude without cumulatively increasing the water surface elevation more than a designated height, generally 300 mm.

Designated Floodway - The channel of a stream and that portion of the adjoining flood plain designated by a regulatory agency to be kept free of further development to provide for unobstructed passage of flood flows. The designated floodway is within the designated flood plain.

Flood Fringe - The portion of the floodplain outside of the floodway but still subject to flooding by inundation. Sometimes referred to as "floodway fringe". Also used to refer to areas subject to flooding by water with velocities less than the floodway area.

Flood Frequency - A statistical expression of the average time period between floods equaling or exceeding a given magnitude. For example, a 100-year flood has a magnitude expected to be equaled or exceeded on the average of once every hundred years; such a flood has a one-percent chance of being equaled or exceeded in any given year. Often used interchangeably with "recurrence interval."

Flood Hazard Areas - The lands adjoining the channel of a river, stream or watercourse which would be covered by flood water during the regulatory flood. These areas embrace those lands frequently designated as floodway and flood fringe or flood plain districts on the official zoning map of the municipality.

Human Intervention - Activation of flood protection systems by manual effort during floods as opposed to activation by automatic means.

Hydrodynamic Loads - Forces imposed on structures by floodwaters due to the impact of moving water on the upstream side of the structure, drag along its sides, and eddies or negative pressures on its downstream side.

Hydrostatic Loads - Those loads or pressures resulting from the static mass of water at any point of floodwater contact with a structure. They are equal in all directions and always act perpendicular to the surface on which they are applied. Hydrostatic loads can act vertically on structural members such as floors, decks, and roofs and can act laterally on upright structural members such as walls, piers, and foundations.

Hydrostatic Pressure - The force resulting when a head (depth) of water, or wet soil, is opposed by a surface such as a wall or basement slab. Hydrostatic pressure is on all surfaces facing the water. The deeper the water, the greater the force exerted.

Infiltration - The flow of fluid into a surface through pores or small openings. The term is commonly used to denote the flow of water into soil.

Impact Loads - Loads induced on a structure by solid objects carried by flood water. They can include trees, lumber, displaced sections of structures, tanks, mobile homes, and chunks of ice. Impact loads are difficult to predict accurately, yet reasonable allowances must be made for them in the design of potentially affected structures.

Natural Boundary - The visible high water mark of any lake, river, stream, or other body of water where the presence and action of the water are so common and usual and so long continued in all ordinary years as to mark upon the soil of the bed of the lake, river, stream, or other body of water a character distinct from that of the banks thereof, in respect to vegetation as well as in respect to the nature of the soil itself.

Nonstructural Measures - All flood plain management measures excepting structural flood control works. Examples of nonstructural measures are flood warning/preparedness systems, relocation, floodproofing, regulation, land acquisition, and public investment policy.

One-Hundred Year Flood - A flood having a one-percent chance of occurring in any given year and which, over a very long period of time, can be expected to be equaled or exceeded on the average of once every hundred years.

100-Year Frequency Flood - A flood having an average frequency of occurrence on the order of once in 100 years although the flood may occur in any year. It is based on statistical analyses of streamflow records available for the watershed and analyses of rainfall and runoff characteristics in the general region of the watershed. The 1% probability means that a major flood of designated magnitude may occur once in 100 years or that there is a 1% chance of such a flood in any year. Normally, the 1% probability of occurrence, based on a flood of specific designated magnitude, is a 'standard' adopted by some provinces and accepted by the Government of Canada.

Permeability - The property of soil or rock that allows passage of water through it.

Regulatory Flood - Same as DFL when adopted by the jurisdiction having authority and incorporated into flood plain management regulations.

Regulatory Floodway - Any floodway referenced in a floodplain ordinance for the purpose of applying floodway regulations.

Seepage - The passage of water or other fluid through a porous medium, such as the passage of water through an earthen embankment or masonry wall.

Setback - Distance away from the natural boundary of the waterbody.

Structural Measures - Flood control works such as dams and reservoirs, levees and floodwalls, channel alterations, seawalls, and diversion channels which are designed to keep water away from specific developments and/or populated areas to reduce flooding in such areas.

Underseepage - Seepage along the bottom of a structure, floodwall, or levee or through the layer of earth beneath it.

Uplift - The upward pressure of water, as on the base of a structure. (See also the term "hydrostatic loads.")

Velocity - The rate of speed that water flows, usually expressed in feet per second. One foot per second is equivalent to about 0.7 mile per hour.

Watercourse - A natural or artificial channel in which a flow of water occurs either continually or intermittently.

Water Table - The uppermost zone of water saturation in the ground.